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ON THE THERMODYNAMIC INTERPRETATION OF ISENTROPIC CHARTS

By HORACE R. BYERS

[Weather Bureau, Washington, D. C., April 1938]

The isentropic chart serves a twofold purpose as (1) a hydrodynamic, and (2) a thermodynamic chart—hydrodynamic in the sense that the paths of "tongues" of maximum water-vapor content serve as identifying indicators of the flow pattern and of lateral mixing; and thermodynamic with respect to indications of adiabatic changes in the air, including water vapor, as it flows along the sloping or broadly undulating isentropic surface. The thermodynamic interpretations will be emphasized in this paper.

As introduced into daily synoptic practice by Rossby and collaborators,[1] the chart usually is drawn to represent a contour map of an isentropic surface, with isograms of specific humidity along the same surface superimposed. Other data, such as winds, relative humidities, clouds, etc., are entered at points of observation with no special representation as to areal distribution. For thermodynamic interpretations it is preferable to use *isobars* in place of elevation contours on the charts, and *isentropic-condensation pressures* instead of specific humidities. In this form, which has been developed and applied in daily practice by the writer and his colleagues, the charts have the same general appearance as the specific humidity-altitude charts, because pressure and altitude are closely related and the condensation pressure along an isentropic surface has only one value for each specific humidity; but the use of condensation pressure and actual pressure has important advantages over the use of specific humidity and altitude, which will be outlined in this article.

Definitions and derivations.—The isentropic-condensation pressure is defined as the total pressure to which air containing water vapor in the unsaturated state must be expanded adiabatically or isentropically without gain or loss of moisture in order to reach saturation. In other words, it is the pressure of the condensation level in an ordinary adiabatic process in the atmosphere. Designating it as p_0, one finds from Poisson's equation that

$$p_0=p\left(\frac{T_0}{T}\right)^{\frac{mC_p}{R}} \tag{1}$$

where T is the temperature at a point with pressure p ($>p_0$) on the isentropic surface; T_0 is the temperature at p_0 (isentropic-condensation temperature); m, the molecular weight of dry air; C_p, the specific heat at constant pressure (work units), and R, the universal gas constant. The definition of the isentropic-condensation pressure requires that the specific humidity (q) shall remain unchanged during the isentropic process, and, making use of this, one obtains the following relations:

$$q=\beta\frac{e}{p}=\beta\frac{e_0}{p_0} \tag{2}$$

$$\frac{p_0}{p}=\frac{e_0}{e}=\left(\frac{T_0}{T}\right)^{\frac{mC_p}{R}} \tag{3}$$

$$p_0=p\frac{e_0}{e}=p\left(\frac{T_0}{T}\right)^{\frac{mC_p}{R}} \tag{4}$$

Here e is the partial pressure of the water vapor and β is the ratio of the molecular weight of water vapor to that of dry air, or 0.622, (q in grams per gram).[2] The values of p_0, T_0 and q as well as the potential temperature can be obtained from any of the thermodynamic charts commonly used in meteorology, such as the Hertz-Neuhoff (pseudo-adiabatic) diagram, Rossby diagram or the tephigram.[3]

To demonstrate that p_0 for any given isentropic surface is a function of q alone, it is necessary to introduce two more equations in addition to (2), since the latter contains three variables. Magnus' formula,

$$e_0=k\epsilon^{\frac{\alpha T_0}{\gamma+T_0}} \tag{5}$$

where ϵ is the base of the natural logarithms and k, α and γ are constants, can be used with the aid of another relation which can be derived from Poisson's equation as follows:

If in (1) $p=1000$ mb, then $T=\theta$, the potential temperature. Along an isentropic surface, then,

$$\theta=T_0\left(\frac{1000}{p_0}\right)^{\frac{R}{mC_p}} \tag{6}$$

and

$$T_0=\frac{\theta}{c}p_0^{\kappa} \tag{7}$$

where $\kappa=\frac{R}{mC_p}$ and $c=1000^{\kappa}$.

[1] Rossby, C. G., and collaborators, Isentropic analysis, *Bul. Am. Meteorol. Soc.*, vol. 18, Nos. 6-7, 1937.

[2] In (2) the denominator should be $p-0.375e$, but e is so small in comparison with p that the above simplification is justified.

[3] Most of these charts give the mixing ratio rather than the specific humidity, but the difference between these two quantities is insignificant in meteorology.

Substituting this value for T_0 in Magnus' formula (5), one obtains

$$e_0=k\epsilon^{\frac{a\theta p_0^{\varkappa}}{b+\theta p_0^{\varkappa}}} \tag{8}$$

where $b=c\cdot\gamma$, and (2) becomes

$$q=\frac{\beta k\epsilon^{\frac{a\theta p_0^{\varkappa}}{b+\theta p_0^{\varkappa}}}}{p_0} \tag{9}$$

which shows that on a given isentropic surface p_0 and q are direct functions of each other.

Some advantages.—An inspection of the Hertz-Neuhoff or similar diagram will show that p_0-isobars on the isentropic chart are better than isograms of specific humidity for representing significant moisture differences at low values of the specific humidity. Figure 1 demonstrates this. The curves are drawn for several isentropic surfaces defined by the potential temperatures 283, 293, 303 and 313, and constructed in accordance with (9). It will be noted that along each isentropic surface $\left(\frac{\partial p_0}{\partial q}\right)_{\theta\text{const.}}$

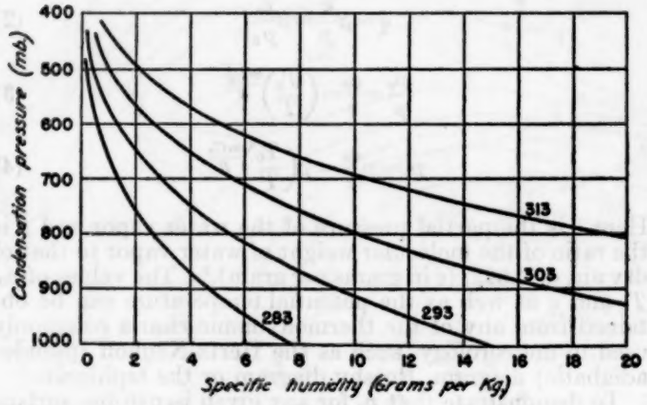

FIGURE 1.

is greatest at low values of q,[4] assuring good representation of moisture differences at low values. While on the isentropic chart a difference in specific humidity between 1 and 0.5 g per kg cannot be represented if q-lines are used, the use of p_0-isobars makes it stand out about as well as the difference between 10 and 5 g/kg. In winter, substantial amounts of precipitation fall out of clouds, in which the specific humidity often is less than 1 g/kg.[5]

The ratio of the partial pressures of the water vapor $\frac{e_0}{e}$, as well as the ratio of the total pressures, $\frac{p_0}{p}$, which in (3) is shown to be an exponential function of the temperature ratio, is a measure of the nearness to condensation. In this sense it is similar to the relative humidity, the latter representing the percentage of saturation with respect to a constant-pressure process while $\frac{e_0}{e}=\frac{p_0}{p}$ measures the fraction of saturation according to an adiabatic or isentropic process. In the analysis of isentropic flow, the ordinary relative humidity has no direct thermodynamic significance. The quantity $\frac{p_0}{p}$ which may be called the "condensation ratio" takes its place.

[4] The equation for the derivative is somewhat complicated and difficult to interpret.

[5] See Lichtblau, S.: Upper-air cold fronts in North America, MONTHLY WEATHER REVIEW, vol. 64, pp. 414–425, 1937.

On the isentropic chart, drawn according to the plan described here, the nearness to condensation is shown by the distance between an isobar and the p_0-isobar which has the same value. Where these two meet, saturation would be indicated; and unless supersaturation is admitted, they cannot cross. In this way, with a reasonably dense network of aerological stations, such as in the United States, the regions of saturation for any one or several isentropic surfaces can be delineated with accuracy. With specific humidity and elevation lines it is not possible to do this without additional labor, and even then the method would not be accurate because, owing to horizontal pressure gradients, the height of the condensation level correspondong to a given specific humidity would not be everywhere the same.

The distance on the chart separating equal p_0- and p-isobars is a good prognostic criterion when considered in relation to the prevailing flow pattern. If in extrapolating the flow into the future it is found that p_0-isobars are overtaking the corresponding p-isobars, saturation and precipitation may be expected to follow. The likelihood of saturation will be indicated especially if the p-gradient $(-\nabla p)$ is greater than $(-\nabla p_0)$.

On the isentropic chart isobars are also isotherms, since $T=\frac{\theta}{c}p^{\varkappa}$ as in (7). Also, it is evident from (7) that p_0-isobars are isotherms of T_0, the condensation temperature. Since the relation is not linear, the pressure gradient cannot be used for obtaining the temperature gradient directly. In airways forecasting and dispatching it is helpful to know the location of the 0° isotherm as an indication of possibilities of ice formation, especially where the p- and p_0-isobars approach each other. It is convenient for this purpose to draw this isotherm in some distinguishing color across the chart. The pressures at the 0° isotherm for various isentropic surfaces is given in the table below.

θ (°A)	p (mb)	θ (°A)	p (mb)	θ (°A)	p (mb)
273	1,000	291	801	309	650
275	975	293	782	311	636
277	950	295	764	313	622
279	928	297	746	315	608
281	905	299	729	317	595
283	883	301	712	319	582
285	861	303	696	321	570
287	841	305	680	323	558
289	820	307	665		

Isobars are also isosteres and isopycnals (lines of equal specific volume and density) on the isentropic surface. This is evident from the following relationships in which v represents the specific volume:

$$T=\frac{\theta}{c}p^{\varkappa}=\frac{pvm}{R} \tag{10}$$

$$v=\frac{R}{m}\frac{\theta}{c}p^{\varkappa-1} \tag{11}$$

The gradient of v is a function of the logarithm of the pressure gradient.

An advantage of isobars over elevation contours is seen in the analysis of the isentropic chart in the region of cold cyclones, which are important features of the circulation in middle to high latitudes. On account of the low temperature, these cyclones are intense at high levels and therefore produce a pronounced pressure minimum

on the upper as well as the lower isentropic surfaces. The low temperature further contributes to an elevation of these surfaces toward low pressures. In terms of altitude, there is no significant effect due to the low pressure. The height of a given surface depends on the temperature in the air column below and is very little affected by the actual values of the pressures. Besides temperature, the difference in the logarithms of the pressures at sea level and at the isentropic surface is the only other variable. The height is given by

$$h=\frac{RT_m}{mg}(\log p_s-\log p) \qquad (12)$$

where T_m is the integrated-mean temperature of the air column and p_s is the pressure at sea level. As an extreme example of the effect of actual pressures on height at a given level, consider a change in p_s and p of 80 mb each. Then for p_s near 1,000 mb and p near 600 mb the change in altitude at a constant mean temperature of 273° A would be only about 40 meters. Thus, regardless of whether the pressure field shows a HIGH or a LOW, the height of the isentropic surface is hardly affected. In terms of pressure, on the other hand, the transition from a high-pressure area to a low-pressure area on an isentropic surface is marked by a slope even if no temperature difference exists. If there is a temperature difference such that the low-pressure area is colder, the slope would be much greater in terms of isobars than in terms of elevation contours. This suggests a considerable amount of solenoidal circulation, which is more to be expected in these cyclones than the rather weak activity suggested by elevation contours.

Due to horizontal pressure gradients a level surface may not be a surface of constant pressure. Furthermore, the isentropic surface may slope in terms of elevation but still be at the same pressure. This and the fact that thermodynamic changes on an isentropic surface really depend only on pressure changes, show that pressure is of more fundamental significance than elevation.

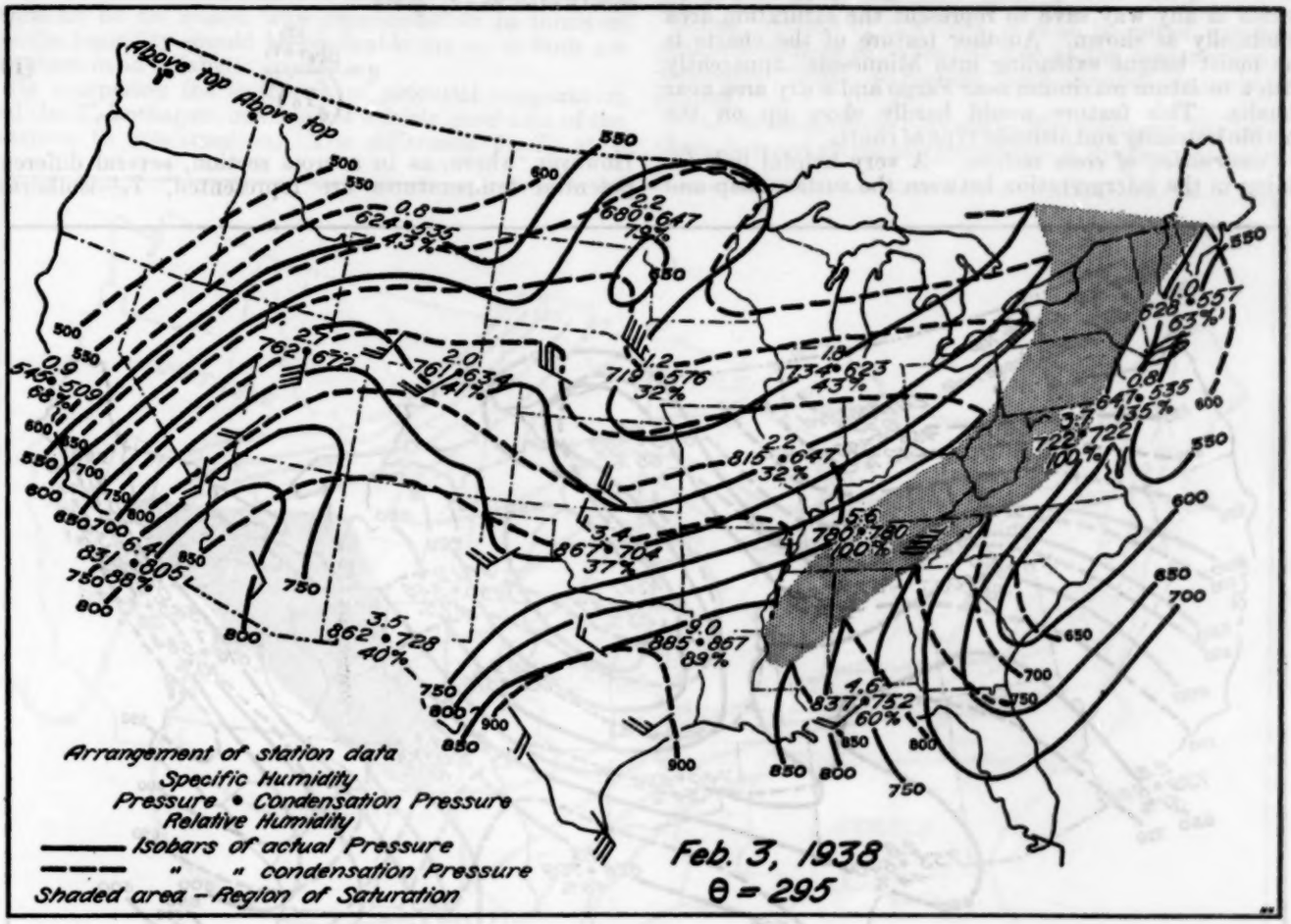

FIGURE 2.

Another great advantage lies in the ease with which the weight of air contained between two isentropic surfaces may be determined. For a vertical cross section of unit area this is given by:

$$\int_{h_{s_1}}^{h_{s_2}}\rho g\,dh=-\int_{p_{s_1}}^{p_{s_2}}dp=p_{s_1}-p_{s_2} \qquad (13)$$

where ρ is the density, g is the gravity acceleration and h measures the height. Thus with two isentropic surfaces charted, the mass contained between them is given by a simple subtraction of the pressures at the various points. The change in this difference in a stated period gives the *isallobaric* contribution of the layers in question.

Examples of charts prepared after the new manner are contained in figures 2 and 3 which represent two surfaces

corresponding to potential temperatures of 295° and 299° for February 3, 1938. The p_0-isobars are drawn with solid lines and the broken lines are the p-isobars. The stippled area represents the region of saturation, found from the points of intersection of the significant isobars, all of which are clearly shown. This area agrees closely with the area of altostratus clouds and precipitation as shown by the surface map. Even without the help of surface reports it is evident that the chart cannot be drawn in any way save to represent the saturation area practically as shown. Another feature of the charts is the moist tongue extending into Minnesota, apparently with a moisture maximum near Fargo and a dry area near Omaha. This feature would hardly show up on the specific humidity and altitude type of chart.

Construction of cross sections.—A very helpful link for aiding in the interpretation between the surface map and the isentropic chart is the atmospheric cross section. My colleague, C. H. Pierce, has found that for the best thermodynamic interpretation these cross sections should be constructed in terms of altitude and distance, with isotherms of potential temperature and iostherms (in °A) of the isentropic-condensation temperature. Isotherms of potential temperature are, of course, isentropic surfaces. These lines show the slope of the isentropic surfaces in the vertical plane of the cross section constructed, and they also give one some idea of the vertical stability between any two chosen surfaces.

Lines of equal condensation temperature show the moisture content of the air. These have similar advantages over isograms of specific humidity as do isentropic-condensation pressures. In the first place, the isentropic-condensation temperature along a given isentropic surface is a direct function of q. This is shown by substituting (5) for e_0 in (2), for from (7) we have $p_0=\left(\frac{c}{\theta}T_0\right)^{1/\kappa}$, which, substituted in (2), gives

$$q=\frac{\beta k\epsilon^{\frac{aT_0}{\gamma+T_0}}}{\left(\frac{c}{\theta}T_0\right)^{1/\kappa}} \tag{14}$$

However, where, as in a cross section, several different potential temperatures are represented, T_0=isotherms would not correspond to q=isograms because for a given condensation temperature the specific humidity would be different for different pressures. This variation of q with $_0p$ at constant temperature can be shown by differentiating (2), holding T_0 constant, which, according to (5) means e_0 constant.

$$\left(\frac{\partial q}{\partial p_0}\right)_{T_0 \text{ const.}}=-\beta\frac{e_0}{p_0^2}=-\frac{q}{p_0} \tag{15}$$

Using ordinary values of q and p_0 one finds that this variation in the specific humidity represented by a given T_0

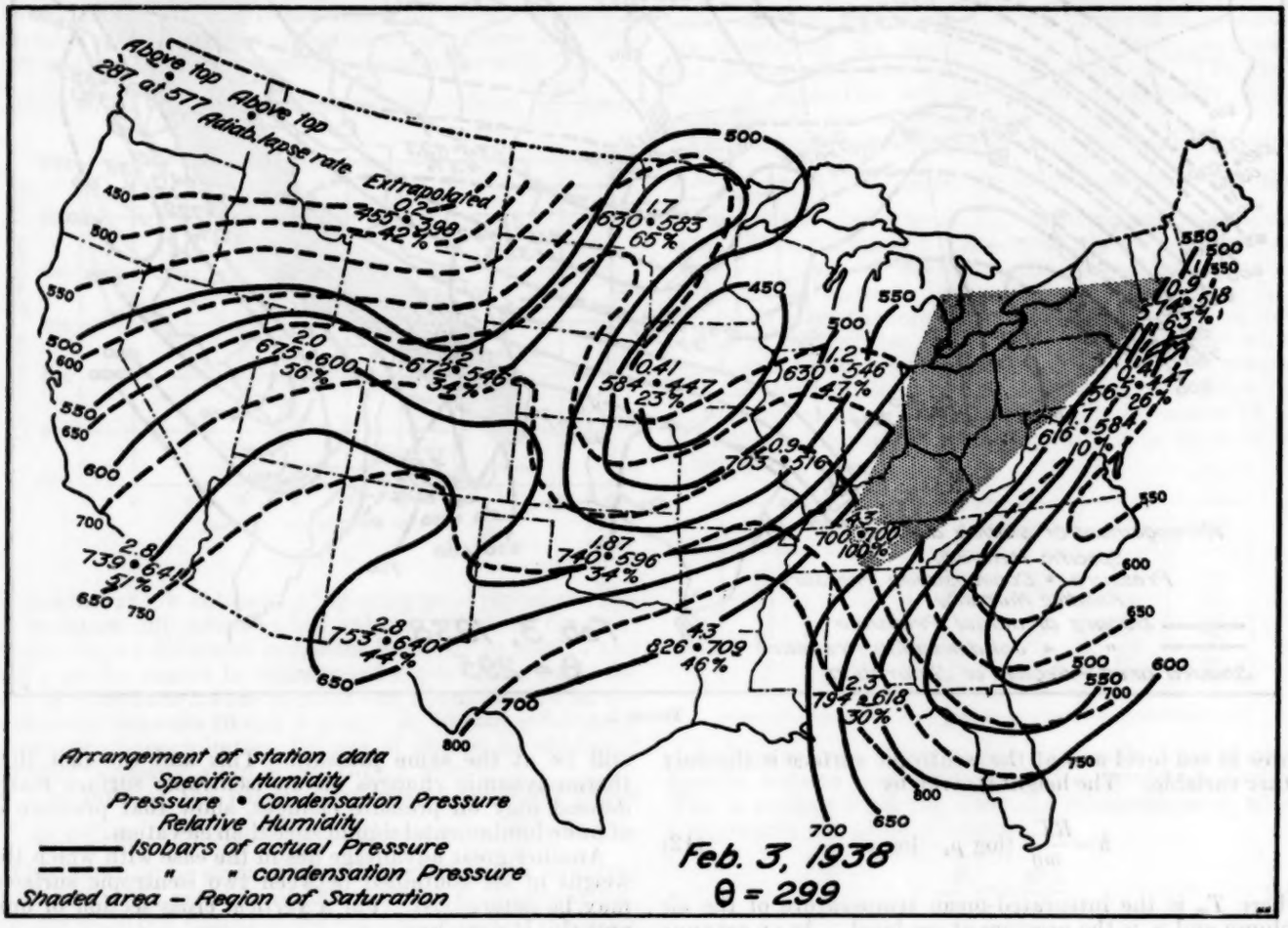

FIGURE 3.

for changing pressure usually is less than 10 percent per 100 mb change. For example, if q is 10 g/kg and p_0 is 1,000 mb, the change would be a 1-gram increase in q per 100 mb ascent in the atmosphere; 0.5 g per 100 mb at a pressure of 500 mb, etc. At 1 g/kg and 1,000 mb the change would be 0.1 g per 100 mb. It is felt that the advantages of using this quantity outweigh this inexactness in the absolute measurement of moisture content. There seems to be no reason why representation in terms of specific humidity should be preferable *per se*, as both are invariant in an adiabatic process.

By comparing the isotherms of potential temperature and the T_0-isotherms, one can get a fairly good idea of the nearness to condensation. The difference $\theta - T_0$ at a point on the cross section shows the number of degrees the air must be cooled to reach condensation if lifted from the 1,000-mb level. It is known that during adiabatic ascent the temperature falls approximately 10° per km. Therefore, if the difference is 25°, saturation would be expected near 2,500 meters; that is, assuming that the sea-level pressure is 1,000 mb, which is seldom the case. However a rough estimate of the height of the 1,000-mb isobar can be made from the pressures of the surface map.

As an illustration, suppose that at 1,000 m over Omaha we find $\theta = 295$ and $T_0 = 275$, making $\theta - T_0 = 20°$. Accordingly one would expect saturation at 2,000 meters above the 1,000-mb surface. If the 295° isentropic surface slopes upward to 2,000 meters toward Chicago and if the sea-level pressure at Chicago is 1,020 mb we add 180 m to the 2,000 m. Assuming that the airflow is from Omaha to Chicago, one would expect saturation slightly to the east of Chicago at 2,180 m above sea level.

Like the condensation pressure, T_0 gives a more representative difference in moisture content at low values. Furthermore, there would be no crowding of these lines when the moisture content is high, as is the case when isograms of specific humidity are used.

Cross sections of this type, it is to be noted, are constructed entirely of isotherms just as the construction of isentropic charts advocated here consists entirely of isobars.

The moist-adiabatic process.—The ordinary isentropic chart does not give a correct picture of the flow pattern for conditions of saturation. After condensation the air follows a saturation-adiabatic or pseudoadiabatic surface with continuously increasing potential temperature. In this process the equivalent-potential temperature is constant. At the condensation level the pressure, p_0, and the potential temperature designate the equivalent-potential temperature surface or pseudoadiabatic which subsequently is to be followed. Since after saturation $p_0 = p$, it is easy to find from thermodynamic charts the rate at which this pseudoadiabatic cuts through the successive potential-temperature (isentropic) surfaces. It is not sufficient, however, to calculate in this way the rate of ascent of the air using the vertical and geographical distribution of potential temperature in the surroundings because condensation immediately alters the field of po-

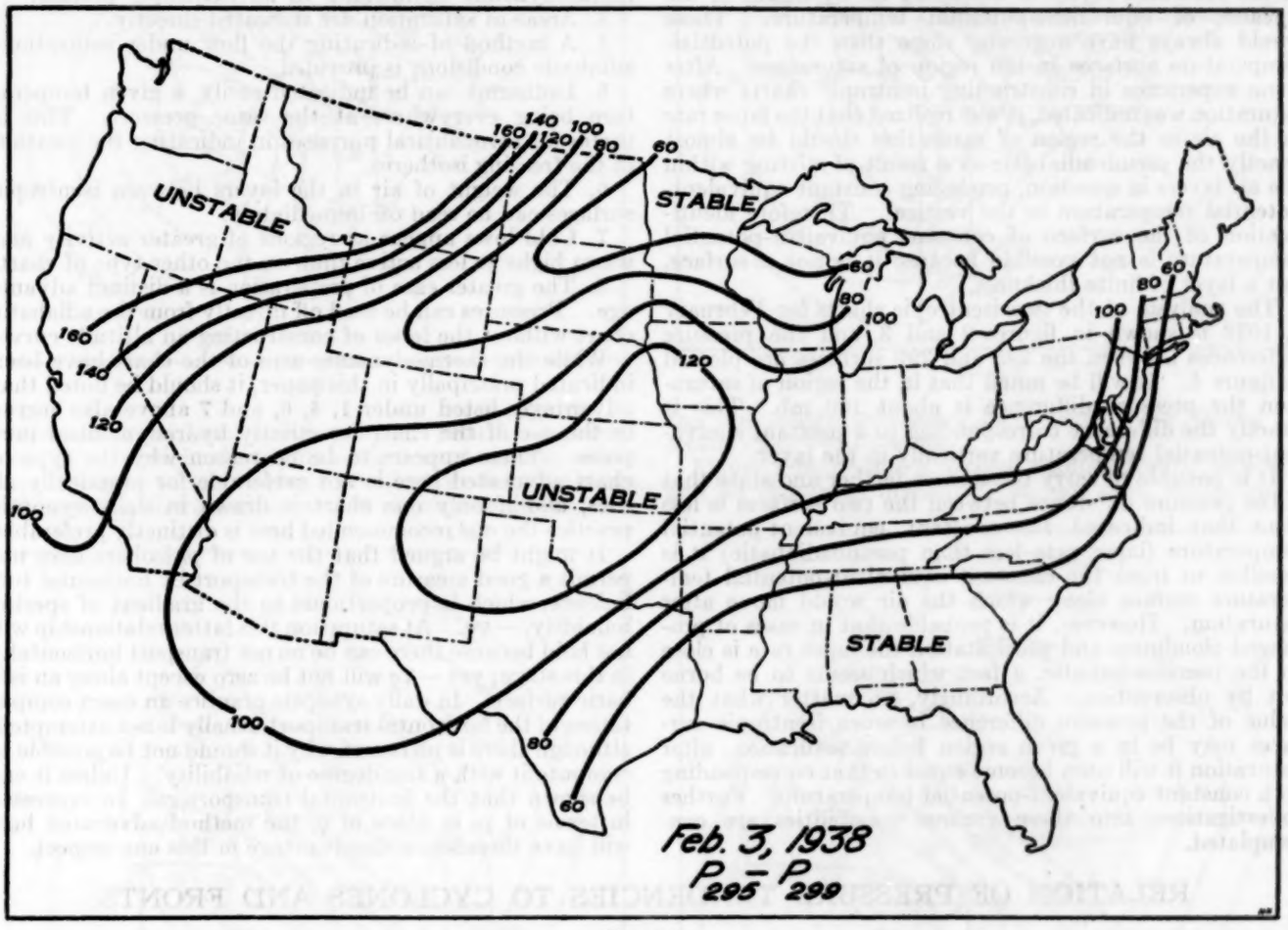

FIGURE 4.

tential temperature. The release of the heat of vaporization from the water vapor upon condensation at any point causes an increase of potential temperature at that point. Thus a lowering of the potential temperature surfaces in the saturated layers occurs.

The transformation from unsaturated to saturated conditions in a region on the isentropic chart is marked by a decrease in the slope of the potential-temperature surfaces. The moist tongues usually flow up a "valley" of the isentropic surface and the effect of saturation in such a "valley" is to change its shape by this decrease in slope.

With a dense network of upper-air soundings in the moist region one would expect to be able to trace the flow in the saturated layers of ascending air by means of the surfaces of equivalent-potential temperature. These would always have a greater slope than the potential-temperature surfaces in the region of saturation. After some experience in constructing isentropic charts where saturation was indicated, it was realized that the lapse rate in the air in the region of saturation should be almost exactly the pseudoadiabatic as a result of stirring within the air layers in question, producing constant equivalent-potential temperature in the vertical. Therefore identification of the surface of constant equivalent-potential temperature is not possible because it is not a surface, but a layer of finite thickness.

The analysis of the two isentropic charts for February 3, 1938 is shown in figures 2 and 3, and the pressure differences between the 295 and 299 surfaces are plotted in figure 4. It will be noted that in the region of saturation the pressure difference is about 100 mb. This is exactly the difference corresponding to a constant equivalent-potential temperature vertically in the layer.

It is possible to carry these ideas farther and state that if the pressure difference between the two surfaces is less than that indicated for constant equivalent-potential temperature (lapse rate less than pseudoadiabatic) it is possible to trace the constant equivalent-potential temperature surface along which the air would move after saturation. However, it is probable that in cases of prolonged cloudiness and precipitation the lapse rate is close to the pseudoadiabatic, a fact which seems to be borne out by observation. Accordingly, no matter what the value of the pressure difference between isentropic surfaces may be in a given region before saturation, after saturation it will soon become equal to that corresponding to a constant equivalent-potential temperature. Further investigations into these various possibilities are contemplated.

Conclusion.—The thermodynamic isentropic chart has the following advantages over the chart based on elevations and specific humidities:

1. Better representation of significant moisture differences at low values. Moist tongues at low temperatures show up as well as those at high temperatures; not so on the other type of chart where with winter temperatures over the continent they may not even appear at all.
2. Nearness to condensation can be determined by the "condensation ratio" p_σ/p directly from the chart and especially by noting on the chart the distance separating a p_σ-isobar and a p-isobar of equal value. This cannot be shown directly with q-isograms. The ratio p_σ/p is the only expression of the nearness to saturation that is of direct thermodynamic significance in an isentropic process.
3. Areas of saturation are indicated directly.
4. A method of indicating the flow under saturation-adiabatic conditions is provided.
5. Isotherms can be indicated easily, a given temperature being everywhere at the same pressure. This is useful for aeronautical purposes in indicating the location of the freezing isotherm.
6. The weight of air in the layers between isentropic surfaces can be read off immediately.
7. Cold lows appear as regions of greater activity and warm highs as less active than on the other type of chart.
8. The greater ease of preparation is a distinct advantage. Pressures can be read off directly from the adiabatic chart without the labor of constructing an altitude curve.

While the thermodynamic uses of the chart have been indicated principally in this paper, it should be noted that advantages listed under 1, 4, 6, and 7 above also accrue in the use of the chart for strictly hydrodynamical purposes. There appears to be no reason why the type of chart advocated here is not preferable for practically all uses, and if only one chart is drawn in daily synoptic practice the one recommended here is distinctly preferable.

It might be argued that the use of p_σ-isobars does not permit a good measure of the transport by horizontal turbulence, which is proportional to the gradient of specific humidity, $-\nabla q$. At saturation this latter relationship will not hold because there can be no net transport horizontally in this stage; yet $-\nabla q$ will not be zero except along an isobaric surface. In daily synoptic practice an exact computation of the horizontal transport usually is not attempted, although there is no reason why it should not be possible to compute it with a fair degree of reliability. Unless it can be shown that the horizontal transport can be expressed in terms of p_σ in place of q, the method advocated here will have therefore a disadvantage in this one respect.

RELATION OF PRESSURE TENDENCIES TO CYCLONES AND FRONTS

By W. R. STEVENS

[Weather Bureau, New Orleans, La., February 1938]

One of the most important elements for forecasting purposes contained in weather reports is the 3-hour pressure tendency. The method developed by Petterssen [1] for determining displacements of pressure centers, wedges, troughs, and fronts, is one of the most valuable tools at the disposal of the forecaster and is based largely on 3-hour pressure tendencies.

It is generally recognized that tendencies are valuable in analysis as well as in prognosis. To illustrate their value, the writer has prepared a set of model moving cyclones, with and without frontal structures. Attention is invited to a study in which Bowie [2] used the same general method in connection with 12-hour pressure changes.

It is emphasized that the 3-hour pressure tendency is only one of many criteria for recognition of a front, and that other data must be given proper consideration.

Each diagram indicates the position of a cyclonic pressure system at the time of observation, as well as 3 hours previously, with attendant pressure changes and characteristics. The changes are larger than ordinarily observed in a 3-hour period, but this is unimportant since they may be divided by any number without affecting the characteristic, which is really the most important factor in analysis.

[1] Petterssen, S.: Kinematical and Dynamical Properties of the Field of Pressure with Application to Weather Forecasting. Geofysiske Publikasjoner vol. X, No. 2.
[2] Bowie, E. H.: On Pressure-Change Charts, MO. WEA. REV., 44: 132-133.

The low-pressure charts of the models are all assumed to be moving without acceleration in a straight line. A radical change in direction of movement of a warm-sector cyclone does not occur within a 3-hour period. Acceleration in a straight line within the same period, while more likely to occur, will have no effect on the net change although the characteristic will be slighlty modified.

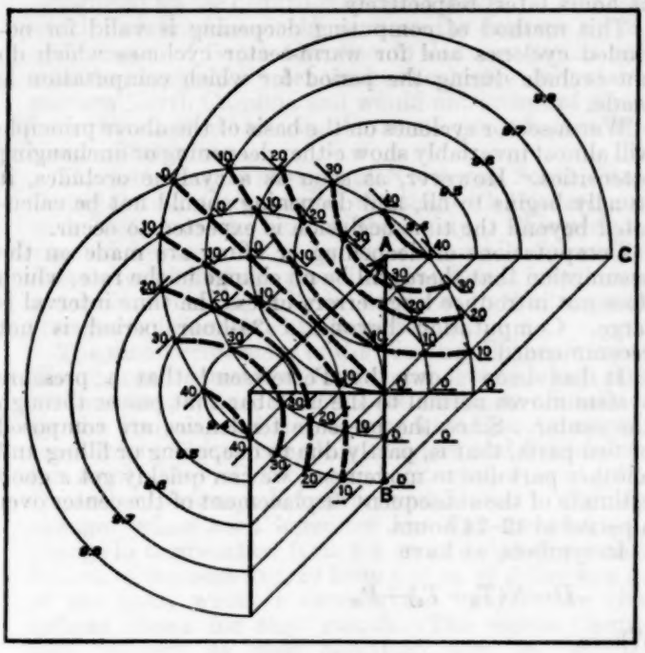

FIGURE 1.

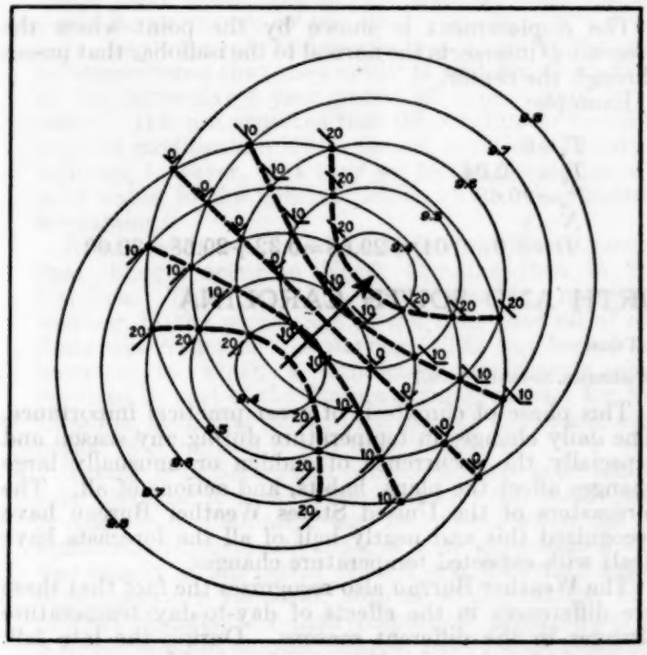

FIGURE 2.

Figure 1 represents a warm-sector cyclone without change in intensity with the cold front AB and the warm front AC retaining the same positions relative to the moving system. It is noted that the tendencies at the warm front are steadily falling and are leveling off in the warm sector with a rather large area where the pressure has been steady. The cold front naturally is marked by the line where tendencies have been either falling (or steady) followed by a rise.

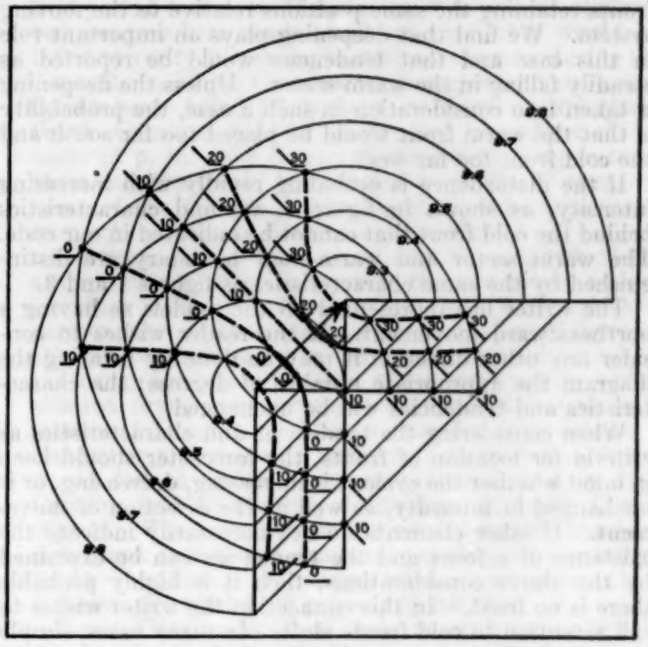

FIGURE 3.

Figure 2 represents a cyclone without frontal structure and no change in intensity. In this case, tendencies in the southeast portion show no leveling off as is found in the warm sector of figure 1 although they are falling less rapidly than during the early part of the period.

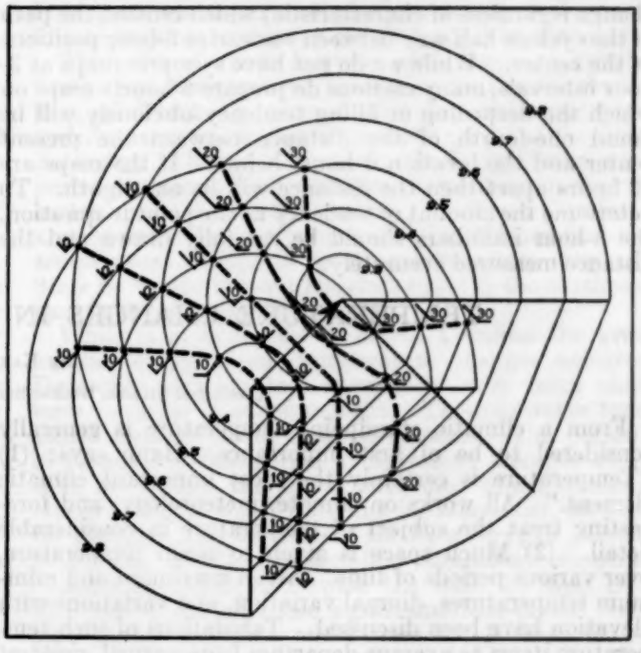

FIGURE 4.

Since provision is not made in our code to distinguish between falling then steady and falling then falling less

rapidly, the characteristics in the latter case might be mistaken to indicate the existence of a frontal structure.

Figure 3 represents a warm-sector cyclone which is increasing in intensity (deepening) with the cold and warm fronts retaining the same positions relative to the moving system. We find that deepening plays an important role in this case and that tendencies would be reported as steadily falling in the warm sector. Unless the deepening is taken into consideration in such a case, the probability is that the warm front would be placed too far south and the cold front too far west.

If the disturbance is occluding rapidly with increasing intensity, as shown in figure 4, we find characteristics behind the cold front that cannot be indicated in our code. The warm sector and warm-front boundary are distinguished by the same characteristics as figures 1 and 3.

The writer has represented all the models as having a northeastward movement. If the reader wishes to consider any other direction it may be done by rotating the diagram the appropriate number of degrees; the characteristics and tendencies will be unchanged.

When considering the tendencies and characteristics as criteria for location of fronts, the forecaster should keep in mind whether the cyclone is increasing, decreasing, or is unchanged in intensity, as well as the direction of movement. If other elements do not necessarily indicate the existence of a front and the tendencies can be explained by the above considerations, then it is highly probable there is no front. In this connection the writer wishes to call attention to cold fronts aloft. In many cases, simple movement of the system will give tendencies which might be interpreted as being associated with a cold front aloft. Therefore, caution should be exercised in locating such a front unless other data, e. g., cloudiness, precipitation, or upper-air soundings, indicate its existence.

It is observed from the models that the deeping or filling tendency is indicated by the 3-hour isallobar (amount of change regardless of characteristic) which crossed the path of the cyclone half way between successive 3-hour positions of the center. While we do not have synoptic maps at 3-hour intervals, many stations do prepare 6 hourly maps on which the deepening or filling tendency obviously will be found one-fourth of the distance between the present center and the location 6 hours before. If the maps are 12 hours apart then the distance will be one-eighth. To determine the amount of tendency at the point in question, the 3-hour isallobars should be carefully drawn and the distance measured accurately.

For example, suppose we have a cyclone with −0.04 tendency one-fourth of the distance from the present center to the position 6 hours before. Then the cyclone should deepen with central pressure 0.16 and 0.32 lower, 12 and 24 hours later, respectively.

This method of computing deepening is valid for occluded cyclones and for warm-sector cyclones which do not occlude during the period for which computation is made.

Warm-sector cyclones on the basis of the above principle will almost invariably show either deepening or unchanging intensities. However, as soon as a cyclone occludes, it usually begins to fill, and deepening should not be calculated beyond the time occlusion is expected to occur.

Computations of deepening or filling are made on the assumption that there will be no change in the rate, which does not introduce large errors unless the time interval is large. Computation beyond a 24-hour period is not recommended.

It has been shown by Petterssen [1] that a pressure system moves normal to the isallobar that passes through the center. Since the pressure tendencies are composed of two parts, that is, partly due to deepening or filling and another part due to movement, we can quickly get a good estimate of the subsequent displacement of the center over a period of 12–24 hours.

In symbols, we have

$$D=N(T_b-T_a)+P_a$$

Where

D=displacement in terms of pressure.
T_b=deepening or filling tendency.
T_a=tendency at the center.
P_a=Pressure at the center.
N=Number of 3-hour periods, e. g., displacement 24 hours hence, $N=8$

The displacement is shown by the point where the pressure D intersects the normal to the isallobar that passes through the center.

Example:

$T_b=0$
$T_a=-0.04$
$P_a=29.68$
$N=8$
$D=8(0+0.04)+29.68=0.32+29.68=30.00$

TEMPERATURE CHANGES IN NORTH AND SOUTH CAROLINA

By EARL C. THOM

[Aerological Division, Weather Bureau, Washington, November 1, 1937]

From a climatic standpoint temperature is generally considered to be of first importance. Hann says: (1) "Temperature is certainly the most important climatic element." All works on climate, meteorology, and forecasting treat the subject of temperature in considerable detail. (2) Much space is given to mean temperature, over various periods of time. Mean maximum and minimum temperatures, diurnal variation, and variations with elevation have been discussed. Tabulations of such temperature items as average departure from normal, greatest daily range, monthly extremes (3), and average 8 a. m., noon, and 8 p. m. temperatures, are to be found (4); but, aside from information on cold waves (5) and two studies on temperature changes affecting Texas (6), little is available treating the subject of changes in temperature from day to day.

This phase of climate is of great practical importance. The daily changes in temperature during any season and especially the occurrence of sudden or unusually large changes affect the plans, habits, and actions of all. The forecasters of the United States Weather Bureau have recognized this and nearly half of all the forecasts have dealt with expected temperature changes.

The Weather Bureau also recognizes the fact that there are differences in the effects of day-to-day temperature changes in the different seasons. During the late fall, winter, and early spring there are more and larger temperature changes than in summer. People become accustomed to larger temperature variations and a considerbly larger change is necessary in winter than in summer to produce the same effects. When stationary temperature has been forecast the change which may occur and still allow the

forecast to verify differs with the season, the Bureau having established differing bases for different months for use in temperature verification.

The difference in effects of temperature change is also recognized by the definition of "cold waves." The change which is defined as a cold wave on the extreme tip of the south coast of South Carolina in January would not be considered especially severe in the higher mountains of western North Carolina and would not be out of the ordinary for that month in the north-central part of the United States.

The temperature changes of North and South Carolina during the eight-year period, starting with 1928 and ending with 1935, form the basis of this study. This period was selected because the maps were conveniently available. It is believed that the period is of sufficient length so that conclusions may logically be drawn as to the temperature changes to be expected in these States.

The manuscript maps of the Weather Bureau were used. The changes were taken from the charts on which lines of 24-hour temperature change were drawn, as officially used by the Bureau, and hence were based on "changes" of more than: 6° for June, July, August, and September; 8° for April, May, October, and November; and 10° for December, January, February, and March. "Significant change" when used hereafter has this meaning, viz, a change in temperature from 8 a. m. of 1 day of a month to 8 a. m. of the next day, or from 8 p. m. of 1 day to 8 p. m. of the next, when it exceeds the temperature change defined above for that month. The words "warmer" and "colder" as used hereafter refer to "significant changes".

The a. m. and p. m. temperature charts for each day of the 8 years were studied and notes in tabular form made. Summary sheets and charts were pepared for each month showing the percentage of the time that a stationary forecast would have verified, the percentage of the time it would have been necessary to forecast that the State would be warmer or colder, etc.

In the statements and conclusions which follow, it is to be remembered that they apply to and are characteristic of the particular 8-year period of time coverd by this study. It is not expected that the conclusions would hold without modification if the period were lengthened; it is believed, however, that they set forth information which is of value to the general public and to the student of forecasting.

In general it was found that more significant temperature changes occur in North Carolina than in South Carolina. There was but little difference, morning or evening, in the percentage of the time that *all* of either State was colder or was warmer. The number of cases, however, in which a significant temperature change occurred in part of the State was much greater for North Carolina, both first period (8 a. m. to 8 a. m.) and second period (8 p. m. to 8 p. m.) (figs. 1 and 2).

Taking both States and considering trends of temperature changes it was noted that: (1) the cold season, November to February, was the period when the most significant temperature changes were experienced and it was usually in this period of each year that the maximum of temperature variation, both as to the number of significant changes and their magnitude occurred; (2) the 5 spring and fall months, March, April, May, September, and October, were months of unstable temperature but with both the number of significant changes and the size of them much less than in winter; (3) the summer, June, July, and August, was a period of stability, with few significant temperature changes.

In the cold season (November to February) significant temperature changes in both States are numerous. Had first-period forecasts (8 a. m. to 8 a. m.) of stationary temperature been made every morning, they would have failed to verify 40 percent or more of the time during these 4 months in North Carolina while corresponding forecasts would have failed 27 percent or more of the time in South Carolina (fig. 1). Likewise, second-period forecasts (8 p. m. to 8 p. m.) of stationary temperature in these months would have failed to verify 37 percent or more of the time in North Carolina and 24 percent or more of the time in South Carolina (fig. 2).

As would be expected, significant temperature changes are found to be more frequent in the cold season in North Carolina than in South Carolina, both first and second periods; also, in both States a larger number of significant changes occur in the first than in the second period.

During the years studied, the largest number of significant first-period temperature changes occurs in the month of December. This is true for both States. In December a first-period stationary temperature forecast would fail to verify 56 percent of the time in North Carolina and 40 percent of the time in South Carolina (fig. 1). The month with the second largest number of significant first-period temperature changes occurring in South Carolina is February, when temperature-change forecasts are needed 33 percent of the time.

North Carolina is more likely to get warmer or colder all over the State for the first period in February than in any other month while South Carolina, for the first period, is most likely to be all warmer in February but is most likely to be all colder in November. In the second period North Carolina is more often colder over all the State in November and in January, while South Carolina is most likely to be colder over the whole State only in January. It is quite unusual for all of either North or South Carolina to be warmer for the second period in winter.

The area of most frequent occurrence of significant first-period temperature change is in the northwestern part of North Carolina during November, December, and January and in the northeastern part of the State in February. During the cold season significant second-period temperature changes are more likely in the northeastern part of North Carolina. In South Carolina the area of most frequent occurrence of significant first-period temperature change is in the northwestern part of the State in November and December and in the northeastern part in January and February.

While it is true that in North Carolina the greatest number of significant temperature changes occurred in December, the greatest number of very large changes were recorded in other months. These extreme temperatures change are of especial interest. The percentage of significant first-period temperature changes of more than 20° (twice the significant base) which occurred in North Carolina was 28 percent for December, 39 percent for January, and 50 percent for February; in November 40 percent of all corresponding significant temperature changes exceeded 16°, twice the base for that month. The percentage of those significant first-period changes recorded in this State, which were 30° (3 times the significant base) or more, was 3 percent for December, 8 percent for January, and 9 percent for February, while 9 percent of the corresponding changes in November were over 24°. Two first-period temperature changes of 40° occur-

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red in January and one in February in North Carolina, and two changes of 32° or over occurred in November.

During the cold season abnormally large changes in morning temperature are more likely to occur in North Carolina with falling than with rising temperature. A morning which was colder than the preceding morning by

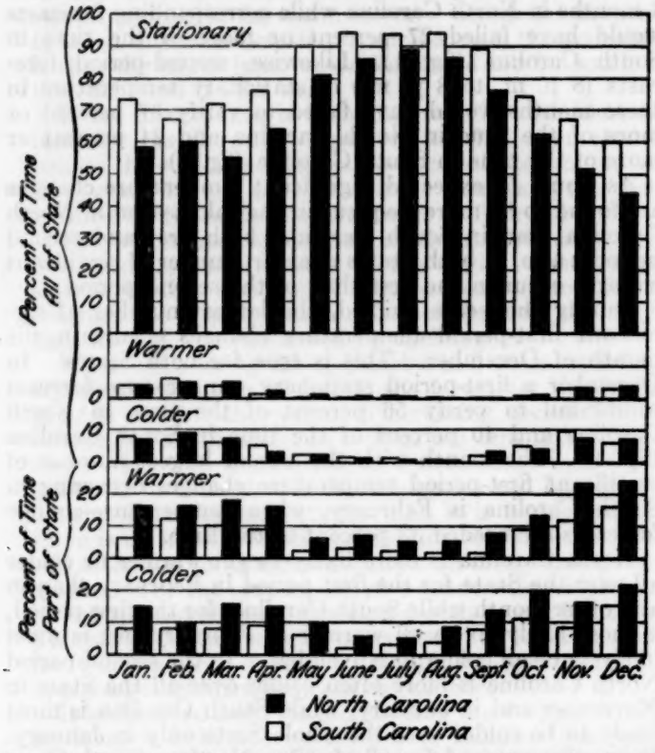

FIGURE 1.—Percentage of the time, 1928 to 1936, that each type of temperature forecast was best for the "first period" (temperature at 8 a. m. of one day compared with the temperature at 8 a. m. of the next day).

three or more times the significant base occurred 20 times during this period while the same amount of change to warmer occurred only 8 times. There were 5 cases recorded during the cold season of the 8 years when the morning temperature was colder by four or more times the significant base and only one case when the same amount of warmer change occurred.

During the 5 spring and fall months temperatures were somewhat unsteady and, in general, more significant temperature changes occurred in March and October than in the other 3 months. In North Carolina a first-period forecast of stationary temperature would have verified 55 percent of the time in March, 62 percent in October, and 81 percent in May (fig. 1). A second-period forecast of stationary temperature for North Carolina would have been good about 52 percent of the time in March and April and about 78 percent of the time in May and September (fig. 2).

During the spring and fall months temperatures are considerably steadier in South Carolina than in North Carolina. A first-period stationary forecast for South Carolina would have verified 72 percent of the time in March and 74½ percent of the time in October, while the same forecast would have verified 90 percent of the time in May (fig. 1). Second-period stationary temperature forecasts in South Carolina would have verified 68 percent of the time in April, 73 percent in March, and 87½ percent in May (fig. 2).

In North Carloina, during the spring and fall, significant temperature changes in both first and second periods are more frequent in the northern half of the State with a somewhat larger number in the northwestern quarter. In South Carolina the significant temperature changes occur with the greatest frequency in the northwestern part of the State.

In both States, spring and fall, the number of significant changes to cooler temperatures was greater than the number to warmer. In the spring months significant second-period temperature changes were of more frequent occurrence in North Carolina than were first-period changes, while in the fall the reverse was true. In South Carolina significant temperature changes are more likely in the second than in the first period during the 3 spring months and during September, while the reverse is true in October.

Summer is the period of steady temperature in both States. North Carolina shows very few significant first-period temperature change in June, July, and August and few second-period changes in July and August. In the 8-year period a stationary first-period forecast would have been best for North Carolina more than 85 percent of the time in summer. A stationary second-period forecast would have been best over 85 percent of the time during the months of July and August only. The largest number of significant changes took place in the northern and western parts of North Carolina, with these changes

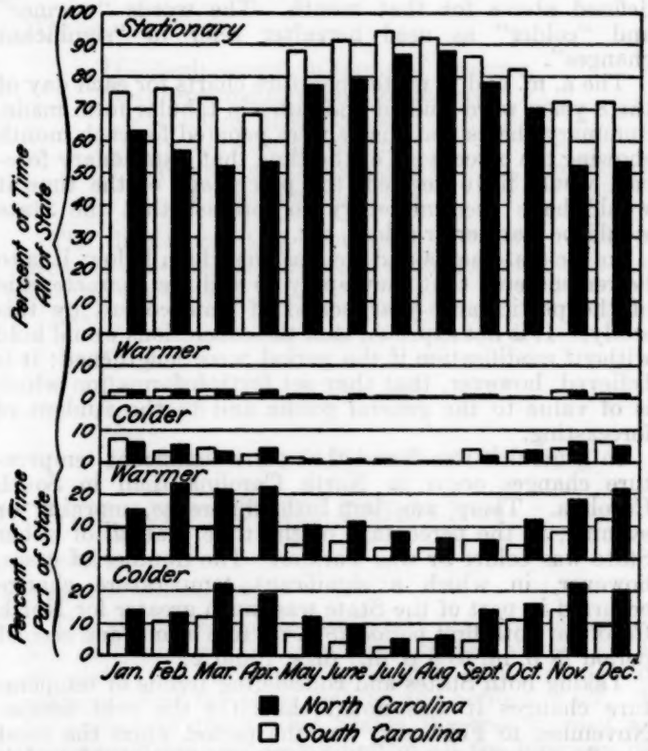

FIGURE 2.—Percentage of the time, 1928 to 1936, that each type of temperature forecast was best for the "second perod" (temperature at 8 p. m. of one day compared with the temperature at 8 p. m. of the next day).

most frequently being noted in the western part and especially at the higher level stations. The number of significant changes recorded in the first and second periods was approximately the same during July and August.

Summer temperatures were even more steady in South Carolina. It appears that for the months of June, July,

and August significant temperature changes are unlikely either first or second period, unless decided departures from normal exist, with indications pointing strongly to change in the opposite direction. A stationary forecast for both first and second periods would have been best over 90 percent of the time in June, July, and August. The number of significant temperature changes in South Carolina in the summer was smaller than the number in North Carolina. This was not due to the whole State of South Carolina getting either warmer or colder less frequently, but to the larger number of occurrences in North Carolina when a section of the State showed a significant 24-hour temperature change.

From these statements it can be inferred that rarely is a "colder" or "warmer" forecast needed for South Carolina in the summer and, further, that attempts to forecast significant changes in portions of this State are not likely to be successful during that season of the year. Most of the significant changes that do occur in South Carolina during the summer are in the northern half of the State, with more in the northwestern part than in the northeastern and with these changes occurring most frequently at the higher elevation stations.

CONCLUSIONS

1. This study shows, as would be expected, that significant temperature changes in the Carolinas are most frequent from November to February, are uncommon from June to August, and are, in most months, more frequent in the areas of higher elevation in the western portions than elsewhere in these States. It shows that significant first-period temperature changes may be expected on nearly 6 days out of 10 in the months of November to February in North Carolina, but on only slightly over 3 days out of 10 in the same months in South Carolina; also, that a significant temperature change occurs on only 1 day out of 10 in the summer, first or second period, in these two States. It is found that large changes are more likely to occur with falling than with rising temperature.

2. This study has dealt only with significant temperature changes within 24 hours (first period, 8 a. m. to 8 a. m., and second period, 8 p. m. to 8 p. m.). Many smaller changes, and some larger changes occurring at other hours, have not been considered. It is believed, however, that the data offered are of interest to the general public, showing an important characteristic of the climate of North and South Carolina. Such data are helpful to the forecaster.

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NOTES AND REVIEWS

I. R. TANNEHILL. *Hurricanes, their Nature and History.* Princeton University Press, 1938.

This book, by the Chief of the Marine Division of the United States Weather Bureau at Washington, deals particularly with the tropical cyclones of the West Indies and the southern coasts of the United States; however, it includes in nontechnical form the essential facts about tropical cyclones in general. The book contains a large amount of information that is not otherwise accessible except in numerous scattered publications, many of which are now difficult to obtain, and in official records.

The introductory chapter is a general description of the principal phenomena of tropical cyclones and of the methods by which information concerning them is obtained. The following six chapters contain detailed discussions of the winds in the hurricane; the destructive storm waves which frequently accompany hurricanes along the coast; facts and theories relating to the origin and maintenance of the hurricane; the tracks followed by the West Indian hurricanes, with charts showing the tracks of all tropical cyclones known to have been of hurricane intensity from 1874 to 1933, inclusive; rainfall and barometric pressure in tropical cyclones. Chapter 7 is an account of the precursory signs of an approaching hurricane. The destructive effects of hurricanes are described in chapter 10; and chapter 11 discusses precautionary measures on land and sea by which losses of life and property may be reduced. Chapter 9 is devoted to statistics of the annual frequency of West Indian hurricanes.

In chapter 8, discussions are given of the tracks of five hurricanes which followed abnormal paths. The remaining four chapters are essentially a history of all tropical storms of record in the West Indian region from 1493 to 1937, including detailed accounts of many of the most memorable storms, chronological lists, and a year-by-year account, with charts, of all storms during the 20th century.

A brief bibliography and an index complete the volume. —*Edgar W. Woolard.*

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[RICHMOND T. ZOCH, *in Charge of Library*]

By AMY D. PUTNAM

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

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Atmospheric potential gradient anomalies. New Haven, Conn. 1936. p. 387–394. tables, diagr. 27 cm. [From Physics, October 1936, vol. 7.]

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Ausbreitung und Verlauf der Grippeepidemie 1933 in Abhängigkeit von meteorologischen und geographischen Faktoren. p. 64–91. maps, tables, diagrs. 20½ cm. Photostated. [From Zeitschrift für Hygiene und Infektionskrankheiten. Bd. 118, Heft 1. Berlin. 1936.]

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SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

SOLAR RADIATION OBSERVATIONS, MARCH 1938

By CHARLES M. LENNAHAN

Measurements of solar radiant energy received at the surface of the earth are made at eight stations maintained by the Weather Bureau, and at nine cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory of Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison. Measurements of the intensity of direct solar radiation through Schott color filters, for the determination of atmospheric turbidity and precipitable water vapor, are conducted at Washington and Blue Hill.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data obtained up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, December 1937, pp. 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parentheses). At Madison and Lincoln the observations are made with the Marvin pyrheliometer; at Washington and Blue Hill they are obtained with a recording Eppley thermopile, checked by observations with a Marvin pyrheliometer at Washington and with a Smithsonian Silver Disk pyrheliometer at Blue Hill. The table also gives vapor pressures at 8 a. m. (seventy-fifth meridian time) and at noon (local mean solar time).

During March 1938 direct solar radiation intensities averaged above normal at Washington; below normal at Lincoln during the afternoon and at Madison; and close to normal at Lincoln in the morning and at Blue Hill.

Table 2 contains the average amounts of radiation received daily on a horizontal surface from both sun and sky during each week, their departures from normal and the accumulated departures since the beginning of the year. The values at most of the stations are obtained from the records of an Eppley pyrheliometer recording on either a microammeter or a potentiometer.

During March 1938 all stations show a deficiency in the total solar and sky radiation for the month with the exception of Chicago, Ithaca, Miami, Fairbanks, New Orleans, San Juan, and Friday Harbor. The latter four stations also had an excess of total radiation during January and February.

For the determination of atmospheric turbidity and precipitable water, the intensity of direct solar radiation at normal incidence is measured, with and without color filters, by a thermopile recording on a potentiometer. The publication of table 3 is temporarily suspended, during a reinvestigation of the transmission of the filters.

No polarization measurements were made at Madison due to continual snow and ice cover, nor at Washington since the polarimeter has not yet been installed.

TABLE 1.—*Solar radiation intensities during March 1938*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 9	3.45				1.09						3.30
Mar. 19	5.36				1.14	1.46					6.02
Mar. 21	7.87				1.26	1.39	1.18				6.76
Mar. 22	7.57				.97	1.14					8.81
Mar. 25	3.45										
Mar. 28	2.36	0.80	0.91	1.10	1.36	1.49	1.19				1.88
Means		(.80)	(.91)	(1.10)	1.16	1.37	(1.18)				
Departures		+.07	+.10	+.15	+.01	−.06	+.04				

MADISON, WIS.

Mar. 1	3.45	0.84	0.97	1.18	1.34						4.37
Mar. 2	6.02	.91	1.06	1.24	1.37	1.64					6.27
Mar. 8	2.26	1.00	1.12	1.23	1.43	1.53					2.36
Mar. 10	3.00				1.06						1.96
Mar. 17	4.57				1.36	1.57					3.99
Mar. 18	5.16		.62	.77							6.76
Mar. 21	6.76	.51	.58	.75	1.00	1.29					8.81
Mar. 30	7.87	.42	.51	.66							8.81
Means		.74	.81	.97	1.26	1.51					
Departures		−.14	−.20	−.18	−.05	−.07					

LINCOLN, NEBR.

Mar. 1	4.17	0.77	0.88	1.09	1.29						5.79
Mar. 6	1.96	1.06	1.20	1.34	1.47	1.66					1.88
Mar. 7	3.00	.90	1.03	1.16	1.33	1.56	1.31	1.15	0.98	0.82	3.81
Mar. 11	4.17	.81	.95	1.12	1.29	1.54					6.02

*Interpolated.

TABLE 1.—*Solar radiation intensities during March 1938*—Con.

LINCOLN, NEBR.—Continued

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 12	6.27		.83		1.28	1.64					5.16
Mar. 16	4.95							1.19	1.10	.99	5.36
Mar. 17	5.16			1.19							5.79
Mar. 19	4.37		1.00	1.06	1.31						4.37
Mar. 20	4.57	.71	.86	1.02	1.23						5.79
Mar. 23	4.17		.72	.92	1.28						2.87
Mar. 24	3.99										
Mar. 25	2.77		.48	.66							6.27
Mar. 27	4.17						1.24	1.04	.89		2.87
Mar. 29	7.87						1.27	.76	.34		5.56
Mar. 31	2.26	.77	.93	1.11	1.31		.89	.75	.59	.47	2.16
Means		.84	.89	1.07	1.31	1.60	1.18	.98	.78	.76	
Departures		.00	−.04	−.02	+.03	+.05	−.10	−.11	−.16	−.05	

BLUE HILL, MASS.

Mar. 2	3.6			0.93	1.07	1.27					3.3
Mar. 6	5.4							1.11	0.96	0.82	3.3
Mar. 7	2.2	0.82	0.93	1.11		1.55	1.31	1.14	.91		2.5
Mar. 9	2.0	.72	.88	1.07	1.30	1.59	1.35	1.20	1.06	.95	1.1
Mar. 11	2.4	.88	.96		1.19	1.32					2.4
Mar. 15	2.4					1.61	1.36	1.16	1.00	.92	2.4
Mar. 19	3.8	.97	1.07	1.18	1.31	1.44	1.25	1.08	.93	.80	4.6
Mar. 21	7.1			1.12	1.30	1.46					4.2
Mar. 22	2.9		.78	.92	1.07	1.27	1.03	.90	.89		3.8
Mar. 24	10.3					1.43	1.32			.99	6.8
Mar. 25	2.9				1.16	1.50	1.16	.95	.81	.70	2.3
Mar. 27	4.0					1.49	1.36				2.9
Mar. 28	2.4			1.04	1.29	1.59	1.22	.94	.74		2.9
Mar. 29	2.9			1.04	1.22	1.37					2.5
Means		.85	.92	1.05	1.21	1.45	1.26	1.06	.91	.86	
Departures		.00	−.01	−.03	−.01	+.04	+.05	+.02	−.04	.00	

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
	Gram-calories per square centimeter																
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Feb. 26	217	224	212	158	260	298	126	250	230	392	372	238	276	566	271	224	299
Mar. 5	262	352	313	275	240	280	211	281	351	436	417	372	336	617	308	268	354
Mar. 12	167	309	288	248	171	403	208	205	468	445	348	409	202	654	225	222	211
Mar. 19	425	280	481	289	406	446	254	291	532	381	390	409	428	569	274	308	473
Mar. 26	273	376	397	351	233	586	341	437	504	469	356	419	331	625	402	255	373
	Departures of daily totals from normals																
Feb. 26	−70	−51	−122	−46	+12	−91	−16	−50	−166	+23	+80	−136	−30	+30	+120	−10	
Mar. 5	−48	+50	−42	+61	−18	−111	+49	−57	−24	+62	+105	−36	+30	+50	+111	+28	
Mar. 12	−150	−8	−81	+27	−89	−5	+10	−123	+48	+20	+14	+4	−75	+78	+29	+13	
Mar. 19	+90	−37	+88	+46	+109	−5	+64	−83	+52	−80	+29	+57	+49	−7	+43	+25	
Mar. 26	−75	+21	−5	+98	−48	+92	+48	+84	−11	+11	+45	+11	−68	+69	+93	−34	
	Accumulated departures since Jan. 1																
	−3,402	−3,430	−2,282	−56	−434	−2,107	+1,862	−4718	−651	−1,001	+2,464	−630	−1,456	+2,490	+3,227	−1421	

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.), Superintendent, U. S. Naval Observatory. Data furnished by the U. S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian, positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

Date	Eastern standard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longitude	Longitude	Latitude	Spot or group	Total for each day		
1938	h m		°	°	°				
Mar. 1	10 58	5799	−67.5	321.5	−17.0	36		3	Mt. Wilson.
		5798	+6.0	35.0	−24.5	73		7	
		5797	+26.0	55.0	−13.0	485		27	
		5791	+37.0	66.0	+7.0	61		11	
		5795	+43.0	72.0	+25.0	121		17	
		5786	+73.0	102.0	−17.0	36		2	
		5796	+84.0	113.0	−6.0	48	860	3	
Mar. 2	12 33	5800	−88.0	286.9	−24.5	242		1	U. S. Naval.
		5799	−53.0	321.9	−17.0	36		3	
		5798	+19.5	34.4	−23.0	36		7	
		5797	+41.0	55.9	−13.0	291		30	
		5795	+55.0	69.9	+24.0	73	678	6	
Mar. 5	14 2	5801	−58.0	276.6	+25.0	291		9	Do.
		5800	−47.0	287.6	−25.0	291		4	
		5799	−14.5	320.1	−17.5	24		4	
		5797	+76.0	50.6	−15.0	97	703	3	
Mar. 6	14 44	5801	−43.0	278.0	+25.0	388		13	Do.
		5800	−34.5	286.5	−25.0	242		4	
		(1)	+17.0	338.0	+23.5	73	703	5	
Mar. 7	11 16	5805	−69.0	240.7	+12.0	291		4	Do.
		5801	−32.0	277.7	+25.0	388		6	
		5800	−23.0	286.7	−25.0	242		2	
		(1)	+30.0	339.7	+23.5	73	994	4	
Mar. 8	10 55	5804	−59.0	237.8	−9.0	97		3	Do.
		5805	−57.0	239.8	+10.5	194		3	
		5801	−20.0	276.8	+24.0	339		10	
		5800	−10.0	286.8	−26.0	242	872	1	
Mar. 9	11 23	5806	−75.0	208.3	+25.0	97		2	Do.
		5804	−45.0	238.3	−9.5	121		6	
		5805	−43.0	240.3	+10.0	145		3	
		5801	−7.0	276.3	+24.0	436		10	
		5800	+3.0	286.3	−26.0	242	1,041	1	
Mar. 10	14 5	5808	−85.0	183.7	−23.0	24		2	Mt. Wilson.
		5807	−77.0	191.7	−17.0	48		2	
		5806	−61.0	207.7	+25.0	97		3	
		5805	−30.0	238.7	+10.0	145		30	
		5804	−28.0	240.7	−9.0	291		44	
		5801	+7.0	275.7	+25.0	727		28	
		5803	+10.5	279.2	−21.0	97		14	
		5800	+17.0	285.7	−26.0	315		12	
		5799	+54.0	322.7	−18.0	48	1,792	10	
Mar. 11	11 14	5808	−70.0	187.1	−24.0	145		10	U. S. Naval.
		5807	−63.0	194.1	−18.0	97		8	
		5806	−48.0	209.1	+24.5	61		4	
		5811	−45.0	212.1	+7.5	12		3	
		5805	−19.0	238.1	+9.0	121		12	
		5804	−15.0	242.1	−10.0	158		38	
		5801	+19.0	276.1	+24.0	727		25	
		5803	+22.5	279.6	−22.0	170		24	
		5800	+29.0	286.1	−26.5	230		1	
		5799	+65.0	322.1	−18.0	73	1,794	8	
Mar. 12	10 33	5808	−58.0	186.2	−24.0	255		14	Do.
		5807	−51.0	193.2	−18.0	61		7	
		5806	−34.0	210.2	+24.5	61		3	
		5805	−4.5	239.7	+9.5	97		6	
		5804	−2.0	242.2	−10.0	339		34	
		5801	+32.0	276.2	+24.0	630		27	
		5803	+35.0	279.2	−23.0	97		8	
		5800	+41.5	285.7	−26.5	291		2	
		5799	+78.0	322.2	−18.5	97	1,928	4	
Mar. 14	11 12	5812	−39.5	178.0	−27.0	24		2	Mt. Wilson.
		5808	−30.0	187.5	−24.0	339		27	
		5806	−9.5	208.0	+24.5	97		8	
		5811	−5.0	212.5	+6.5	12		2	
		5810	+18.0	235.5	+13.0	48		5	
		5805	+22.5	240.0	+9.0	97		10	
		5804	+26.0	243.5	−10.0	921		50	
		5801	+59.0	276.5	+23.0	630		13	
		5803	+60.0	277.5	−26.0	48		4	
		5800	+67.0	284.5	−27.0	242		2	
		5809	+67.0	284.5	−22.0	36	2,404	2	
Mar. 15	11 11	5815	−79.0	125.4	+13.0	24		2	Do.
		5814	−73.0	131.4	+7.0	48		2	
		5813	−61.0	143.4	−11.0	48		5	
		5812	−40.0	164.4	−11.5	48		6	
		5808	−18.0	186.4	−25.0	242		16	

(1) Not numbered.

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longitude	Longitude	Latitude	Spot or group	Total for each day		
1938			°	°	°				
Mar. 15	11 11	5806	+3.0	207.4	+25.0	73		4	
		5811	+9.0	213.4	+7.0	36		4	
		5810	+31.0	235.4	+13.0	36		3	
		5805	+35.0	239.4	+9.5	73		1	
		5804	+39.0	243.4	−9.5	873		37	
		5803	+74.0	278.4	−26.0	97		2	
		5801	+75.0	279.4	+23.0	388		7	
		5800	+79.0	283.4	−27.0	242	2,228	1	
Mar. 16	h m 11 3	5816	−76.0	115.3	−9.0	388		10	Do.
		5815	−67.0	124.3	+12.0	48		2	
		5814	−60.0	131.3	+7.0	24		1	
		5813	−47.0	144.3	−11.0	97		10	
		5812	−26.0	165.3	−11.0	48		4	
		5808	−6.0	185.3	−24.0	291		34	
		5806	+17.0	208.3	+25.0	61		1	
		5811	+22.0	213.3	+7.0	97		11	
		5810	+45.0	236.3	+14.0	24		1	
		5805	+50.0	241.3	+9.0	48		1	
		5804	+54.0	245.3	−9.0	727	1,853	45	
Mar. 17	13 55	5816	−61.0	115.5	−8.0	533		13	Do.
		5815	−51.0	125.5	+13.0	24		2	
		5814	−44.5	132.0	+7.0	24		1	
		5813	−33.0	143.5	−11.0	97		7	
		5808	+9.5	186.0	+23.0	242		19	
		5806	+31.0	207.5	+25.0	61		1	
		5811	+38.0	214.5	+7.0	97		8	
		5805	+65.0	241.5	+9.0	48		1	
		5804	+71.0	247.5	−8.0	582	1,708	20	
Mar. 18	12 33	5816	−49.0	115.1	−8.0	533		30	U. S. Naval.
		5815	−35.0	129.1	+13.0	24		2	
		5814	−32.0	132.1	+7.0	24		1	
		5813	−20.0	144.1	−11.0	24		4	
		5808	+21.0	185.1	−23.5	97		10	
		5806	+42.0	206.1	+25.0	73		1	
		5817	+45.0	209.1	+29.0	97		10	
		5811	+50.5	214.6	+7.0	36		4	
		5805	+78.0	242.1	+9.5	48		1	
		5804	+82.0	246.1	−9.0	388	1,344	4	
Mar. 19	11 5	5818	−88.0	63.7	−12.0	388		2	Do.
		5816	−36.0	115.7	−8.0	388		32	
		5814	−20.0	131.7	+7.5	16		2	
		↓	+20.0	171.7	+17.0	12		4	
		5808	+36.0	187.7	−23.0	36		5	
		5806	+55.0	206.7	+25.0	73		1	
		5817	+59.0	210.7	+29.5	97		6	
		5811	+66.0	217.7	+7.0	12	1,022	2	
Mar. 20	11 50	5818	−89.0	49.1	−17.0	242		3	Mt. Wilson.
		5818	−74.0	64.1	−13.0	776			
		5816	−22.0	16.1	−8.0	388		30	
		5814	−7.5	130.6	+7.0	36		2	
		5808	+50.0	188.1	−23.0	48		5	
		5806	+69.5	207.6	+25.0	61		1	
		5817	+73.0	211.1	+29.0	242	1,793	8	
Mar. 21	11 18	5818	−76.0	49.2	−15.5	873		4	U. S. Naval.
		5818	−61.0	64.2	−12.0	679		8	
		5816	−9.0	116.2	−7.0	291		30	
		5819	+22.5	147.7	−2.5	12		1	
		5820	+51.0	176.2	+30.0	36		3	
		5808	+61.5	186.7	−23.0	24	1,915	2	
Mar. 22	11 3	5818	−63.0	49.2	−15.0	873		2	Do.
		5818	−48.0	64.2	−12.0	727		6	
		5822	−44.5	67.7	−5.0	73		3	
		5821	+0.5	112.7	−27.0	48		6	
		5816	+6.0	118.2	−8.0	170		15	
		5820	+68.0	180.2	+28.0	48	1,939	2	
Mar. 23	11 16	5818	−50.0	48.8	−16.0	873		16	Do.
		5818	−35.9	63.8	−12.5	679		14	
		5822	−30.0	68.8	−4.5	48		6	
		5824	+15.0	113.8	−4.0	24		4	
		5821	+15.5	114.3	−26.0	6		1	
		5816	+19.0	117.8	−8.0	145	1,775	11	
Mar. 24	11 28	5818	−37.0	48.6	−16.0	873		11	Do.
		5818	−21.0	64.6	−13.0	679		8	
		5822	−16.0	69.6	−4.0	24		3	
		5823	+30.0	115.6	+13.0	36		1	
		5816	+31.0	116.6	−8.0	97		5	
		5825	+53.0	138.6	−41.5	36	1,745	1	
Mar. 25	11 6	5818	−23.0	49.6	−17.0	776		14	Do.
		5818	−8.5	64.1	−13.0	630		11	
		5816	+46.0	118.6	−7.0	61		2	
		5825	+68.0	140.6	−41.5	36	1,503	2	
Mar. 26	13 8	5826	−88.0	330.3	−21.0	194		1	Mt. Wilson.
		5818	−9.0	49.3	−17.0	776		18	
		5818	+6.0	64.3	−13.0	630			
		5816	+61.0	119.3	−6.0	36	1,636	1	

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longitude	Longitude	Latitude	Spot or group	Total for each day		
1938	h m		°	°	°				
Mar. 27	12 32	5826	−76.0	329.4	−20.5	242	.....	2	U. S. Naval.
		5818	+3.0	48.4	−17.0	727	.....	12	
		5818	+19.0	64.4	−13.0	630	.....	5	
		5816	+75.0	120.4	−6.0	12	1,611	1	
Mar. 28	11 13	5827	−63.0	329.9	−15.0	24	.....	1	Do.
		5826	−61.0	331.9	−20.0	206	.....	1	
		5818	+17.0	49.9	−17.0	727	.....	11	
		5818	+32.0	64.9	−13.0	630	1,587	3	
Mar. 29	11 19	5827	−51.0	328.7	−15.0	48	.....	5	Do.
		5826	−50.0	329.7	−21.0	291	.....	7	
		5818	+30.0	49.7	−17.0	727	.....	12	
		5818	+45.0	64.7	−12.0	630	1,696	4	
Mar. 30	10 59	5827	−37.0	329.7	−15.0	73	.....	7	Mt. Wilson.
		5826	−36.0	330.7	−21.0	388	.....	10	
		5828	+11.5	18.2	−21.0	73	.....	5	
		5818	+44.0	50.7	−17.0	727	.....	18	
		5818	+59.0	65.7	−13.0	630	1,891	.....	
Mar. 31	11 37	5831	−80.0	273.1	−13.0	291	.....	3	Do.
		5830	−78.0	275.1	−26.0	145	.....	1	
		5829	−70.0	283.1	+22.0	24	.....	1	
		5827	−23.0	330.1	−16.0	73	.....	6	
		5826	−22.0	331.1	−21.0	436	.....	8	
		5828	+27.0	20.1	−20.0	48	.....	6	
		5818	+57.0	50.1	−17.0	727	.....	15	
		5818	+73.0	66.1	−12.0	630	2,374	.....	

Mean daily area for 28 days=1553.

PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR MARCH 1938

[Dependent alone on observations at Zurich and its station at Arosa]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen, Sternwarte, Zurich, Switzerland]

March 1938	Relative numbers	March 1938	Relative numbers	March 1938	Relative numbers
1	74	11	*Ec* 134	21	86
2	*d* 67	12	*a* 124	22	*a* 64
3	62	13	161	23	71
4	*d* 45	14	149	24	66
5	43	15	*Mc* 145	25	59
6	*Wc* 52	16	*d* 159	26	*b* 34
7	*d* 78	17	*a* 138	27	*d*
8	*Ec* 71	18	105	28	55
9	*a* 97	19	80	29	*Mc* 65
10	*Mac* 106	20	*d* 77	30	73
				31	*d* 86

Mean: 30 days=87.5.

a=Passage of an average sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a group developing into a middle sized or large center of activity; E: on the eastern part of the sun's disc; W: on the western part; M: in the central circle zone.
d=Entrance of a large or average sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in Charge]

By L. P. HARRISON

Mean free-air data based on airplane weather and radiometeorograph observations during the month of March 1938 are given in table 1, which includes the basic elements, barometric pressure, temperature, and relative humidity at various standard geometric heights. (Information regarding the methods by which the "means" have been computed is given in the February 1938 MONTHLY WEATHER REVIEW, Aerological Observations.)

Chart I shows that the mean *surface* temperatures during March were generally above normal over the country except in the extreme West including most of California, Nevada, Oregon, southern Idaho, Utah, and Arizona, where they were below normal.

Table 1 indicates that the mean free-air relative humidities, as in February, were relatively high near Nashville, Tenn., and Spokane, Wash., in comparison to those which prevailed over adjacent regions. They were also relatively low near Pensacola, Fla., at elevations from 2 to 5 kilometers, and generally low in this layer over the extreme southern part of the country except near the California coast, as well as moderately low along the middle Atlantic coast.

Isobaric charts prepared on the basis of mean monthly free-air barometric pressures over the country during March show the locus of the statistical center of low pressure in the lower strata to have been near Fargo, N. Dak., and Sault Ste. Marie, Mich., with the center of high pressure to the southeast near the Florida Peninsula. In the upper levels (3–5 km), the centers were near Sault Ste. Marie, and the Gulf of Mexico respectively. In these levels also, the pressures over central and southern California averaged slightly lower than those over the areas immediately to the east.

Table 2 shows the free-air resultant winds based on pilot-balloon observations made near 5 a. m. (75th meridian time) during March. The resultant wind directions were generally normal over most of the country, with certain exceptions. At Pensacola, Fla., in the stratum 0.5 to 3 kilometers, the monthly resultants were oriented counterclockwise with respect to the normal by amounts diminishing with height from 200° to 30°. Near Key West, at 2.5, 3, and 4 kilometers, the similar orientations were about 55°, 20°, and 35° respectively. At Oakland, Calif., within the stratum 0.5 to 2 kilometers, the resultants were about 80° to 40° counterclockwise from normal. Similarly at San Diego, Calif., the amounts were about 35° to 20°, diminishing to about 10° at 5 kilometers. In the same way at elevations from 2 to 3 kilometers over Seattle, Wash., the counterclockwise departures were 30° to 65°; from 3 to 4 kilometers, mean sea level, at Salt Lake City, Utah, 30° to 45°; at Omaha, Nebr., from 0.5 to 2.5 kilometers, 65° to 15°; and at Sault Ste. Marie, Mich., same elevations, 105° to 25°.

The monthly resultant velocities of the free-air winds were generally within ±2 meters per second of the normals. The stations having departures in excess of 3 meters per second and the values thereof were as follows: 0.5 kilometer, Pensacola +3.5 m. p. s.; Cincinnati +3.1; Oklahoma City +3.3; 1 kilometer, Pensacola +3.0; Cincinnati +4.5, Chicago +3.2, Oklahoma City +5.3; 1.5 kilometers, Cincinnati +3.6, St. Louis +3.0, Oklahoma City +4.1; 2 kilometers, Oklahoma City +4.5; 2.5 kilometers, Oklahoma City +3.7, Sault Ste. Marie +3.5, San Diego +3.4; 3 kilometers, Pensacola −3.8, Sault Ste. Marie +4.0, Boston −4.6, Seattle +5.2; 4 kilometers, Key West −4.3, Atlanta −3.3, Sault Ste. Marie +5.8, Albuquerque +3.5, San Diego +3.6; 5 kilometers, San Diego +6.2.

Table 3 shows the maximum free-air wind velocities and their directions for various sections of the United States during March as determined by pilot-balloon observations. The extreme maximum was 70.0 meters per second from the west-southwest at 4,700 meters, mean sea level, over Albuquerque, N. Mex., on March 4.

TABLE 1.—*Mean free-air barometric pressure (P) in mb., temperature (T) in ° C., and relative humidities (R. H.), in percent, obtained by airplanes or radiometeorographs during March 1938*

Stations	Altitude (meters) mean sea level																											
	Surface				500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
	Number of obs.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.
Barksdale Field, La.[1] (52 m)	29	1,008	14.9	83	956	15.3	68	902	14.1	59	849	12.2	51	800	10.2	44	752	7.4	43	708	4.3	42	625	−1.5	34			
Billings, Mont.[2] (1,090 m)	31	886	−0.1	73							842	1.1	61	790	−1.6	61	742	−4.6	62	696	−8.3	66	610	−15.3	68	534	−22.6	62
*Boston, Mass. (5 m)	27	1,014	2.6	78	953	0.6	77	896	−0.8	76	840	−2.0	75	790	−3.0	74	739	−5.3	72	695	−7.4	70	610	−12.6	64	534	−18.7	59
Cheyenne, Wyo.[2] (1,873 m)	29	805	0.6	68										793	1.0	63	744	−2.0	61	699	−5.0	61	614	−11.5	63	538	−18.6	61
Coco Solo, C. Z.[3] (15 m)	29	1,010	24.9	83	955	22.6	88	903	19.9	84	851	16.9	80	803	14.7	67	756	12.9	55	712	10.6	46	631	5.4	31	559	0.8	23
El Paso, Tex.[2] (1,194 m)	31	880	9.8	42							848	12.2	34	799	9.0	34	751	5.3	36	706	2.1	35	623	−4.3	34	548	−11.2	33
Fargo, N. Dak.[2] (274 m)	31	978	−1.8	86	950	0.5	74	892	−0.2	62	838	−2.2	58	786	−3.9	57	738	−6.3	57	692	−8.4	56	607	−14.0	54	532	−19.9	52
Kelly Field, Tex.[1] (206 m)	25	991	16.2	73	958	17.6	62	903	16.5	57	851	14.8	47	802	12.4	42	755	9.6	37	710	6.8	36	628	0.2	32	554	−7.8	33
Lakehurst, N. J.[2] (39 m)	20	1,013	2.8	73	956	4.0	57	898	1.4	52	844	−0.9	51	793	−2.7	47	744	−5.5	46	698	−8.4	43	612	−14.5	41	536	−21.1	40
Maxwell Field, Ala.[1] (52 m)	31	1,012	15.8	74	950	14.6	70	904	12.3	69	852	9.9	64	802	7.6	53	754	5.6	41	709	3.0	34	625	−3.2	29	551	−9.6	31
Mitchel Field, N. Y.[1] (29 m)	24	1,014	2.6	78	957	3.5	68	900	2.0	65	845	0.0	59	794	−2.1	55	745	−3.7	49	699	−6.1	46	615	−12.1	44			
Nashville, Tenn.[2] (180 m)	31	994	11.3	75	957	11.9	72	902	9.8	71	848	7.9	63	798	5.8	58	750	3.1	56	705	0.0	52	621	−5.8	47	546	−12.9	51
Norfolk, Va.[2] (10 m)	20	1,021	9.4	75	962	10.1	53	905	7.5	48	851	5.9	45	801	3.9	43	752	1.4	42	707	−1.6	42	622	−7.5	37	546	−13.3	36
Oakland, Calif.[3] (2 m)	31	1,018	9.7	80	958	7.3	77	902	4.0	77	847	1.1	73	796	−1.5	67	746	−3.8	61	701	−6.4	57	615	−12.5	52	540	−18.3	49
Oklahoma City, Okla.[2] (391 m)	31	966	10.5	76	953	12.2	66	898	12.0	58	846	10.8	48	796	8.3	43	749	5.4	40	704	2.1	40	621	−4.6	41	546	−11.5	41
Omaha, Nebr.[2] (300 m)	30	976	4.6	77	952	5.5	70	896	5.4	62	843	4.1	58	792	1.9	54	744	−0.9	54	699	−3.9	49	614	−10.6	51	539	−17.1	48
Pearl Harbor, T. H.[3] (6 m)																												
Pensacola, Fla.[3] (13 m)	27	1,018	16.5	87	961	16.8	64	906	14.6	58	853	12.5	50	804	9.9	38	756	7.4	35	711	5.1	30	628	−0.6	24	554	−7.2	26
St. Thomas, V. I.[3] (8 m)	30	1,018	24.3	70	961	19.5	77	907	15.7	77	855	12.4	75	805	10.0	71	757	9.0	57	713	7.8	42	631	3.3	28	557	−2.8	22
Salt Lake City, Utah[2] (1,288 m)	31	868	2.6	72							846	3.5	62	794	0.6	60	746	−2.9	63	700	−6.5	67	614	−13.5	69	538	−20.2	63
San Diego, Calif.[3] (10 m)	30	1,016	9.8	89	958	9.4	83	902	6.8	76	848	4.0	70	798	2.1	64	749	0.5	57	704	−2.2	53	619	−8.0	48	546	−15.1	49
Sault Ste. Marie, Mich.[2] (221 m)	27	986	−5.2	81	952	−4.1	74	893	−5.2	70	838	−6.4	64	786	−7.2	56	736	−8.8	53	690	−11.0	52	605	−16.1	56	528	−22.5	54
Scott Field, Ill.[1] (135 m)	19	1,002	6.3	81	959	8.7	59	902	7.2	53	848	5.8	47	798	3.4	46	749	1.1	43	704	−1.7	41	620	−8.2	40			
Seattle, Wash.[3] (10 m)	15	1,013	6.9	77	954	5.2	68	898	2.3	68	842	−1.2	68	791	−4.7	66	742	−8.0	61	697	−10.4	54	614	−17.3	44			
Selfride Field, Mich.[1] (177 m)																												
Spokane, Wash.[2] (597 m)	31	941	2.3	86				896	2.7	76	842	−0.5	76	790	−4.8	80	741	−9.0	82	694	−12.7	80	607	−20.1	71	530	−27.9	71
Washington, D. C.[3] (13 m)	27	1,017	7.0	75	958	7.4	67	902	5.2	67	848	3.9	62	797	2.1	57	748	−0.5	53	703	−3.1	51	618	−8.2	46	543	−14.7	45
Wright Field, Ohio[1] (244 m)	24	987	5.2	81	956	6.4	74	900	6.0	69	846	5.1	60	796	3.0	51	748	0.6	50	703	−2.0	44	618	−8.4	40	543	−14.5	41
*Burbank, Calif. (220 m)	30	990	7.2	81	956	8.9	74	901	6.6	71	846	4.1	66	797	1.6	62	746	−0.6	58	703	−2.5	55	618	−8.0	53	542	−14.3	49
Chicago, Ill.[2] (187 m)	30	991	4.0	79	953	4.4	72	897	3.7	68	843	2.4	64	792	0.3	64	743	−2.0	57	698	−4.7	52	613	−10.6	51	539	−16.8	49

Stations	Altitude (meters) mean sea level																											
	6,000				7,000			8,000			9,000			10,000			11,000			12,000			13,000			14,000		
	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.
Boston, Mass.	466	−25.0	56	406	−32.1	54	351	−38.7	53	303	−43.4		261	−46.4		225	−47.8		193	−49.2		166	−48.3		142	−48.1	
Burbank, Calif.	475	−20.8	48	414	−26.9	48	360	−32.9	47																		

Stations	Altitude (meters) mean sea level																											
	15,000				16,000			17,000			18,000			19,000			20,000			21,000			22,000					
	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.			
Boston, Mass.	123	−48.4		106	−48.8		91	−47.4		78	−46.9		68	−48.3		58	−48.1		50	−48.0		44	−47.4				

*Observations by radiometeorograph. Stations not so marked have observations by airplane. [1] Army. [2] Weather Bureau. [3] Navy.
Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during March 1938*

[Wind from N=360°, E=90°, etc.]

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Billings, Mont. (1,088 m)		Boston, Mass. (15 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (153 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (283 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)		Nashville, Tenn. (194 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	251	1.0	297	1.1	268	2.8	292	1.1	263	4.6	242	1.2	210	1.2	244	1.9	220	0.8	139	1.4	116	2.7	103	0.5	195	3.6
500			262	2.0			297	6.7			249	6.3	236	6.2	259	6.4	254	3.7	187	5.5	118	5.5	143	0.9	214	6.7
1,000			261	4.6			305	9.6			267	8.6	250	10.9	272	8.8	278	4.8	221	4.0	131	3.8	192	2.2	246	9.5
1,500			257	7.3	261	6.9	308	10.7			270	9.5	257	11.4	281	8.2	274	6.5	258	3.8	121	1.4	205	3.7	263	8.6
2,000	263	4.5	267	6.8	264	7.2	300	11.2	270	5.9	280	9.3	278	8.7	283	7.8	274	8.3	276	4.2	233	0.2	212	4.4	279	7.6
2,500	262	6.9	266	9.2	271	7.7	287	9.8	265	9.8	302	8.8	296	9.6	287	8.5	279	10.7	275	7.1	305	0.9	236	4.0	273	8.0
3,000	261	9.8	280	10.4	280	7.7	282	8.9	270	10.7			294	10.3	300	8.6	291	11.5	277	8.5	290	0.8	213	3.5	269	6.0
4,000	261	14.5	276	9.8	271	9.0			271	12.4							291	9.2			321	2.3				
5,000	277	12.6			262	5.9																				

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during March 1938*—Con.

	Newark, N. J. (14 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Pearl Harbor, Territory of Hawaii [1] (68 meters)		Pensacola, Fla.[1] (24 meters)		St. Louis, Mo. (170 meters)		Salt Lake City, Utah (1,294 meters)		San Diego, Calif. (15 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Spokane, Wash. (603 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	266	2.1	149	0.7	183	2.4	76	0.5	47	3.3	118	1.7	222	1.8	163	3.4	96	0.3	110	0.2	158	1.9	168	1.7	269	1.0
500	273	7.3	243	2.1	195	5.3	235	0.9	65	6.2	170	4.1	233	5.7	------	------	260	1.7	252	1.7	193	4.2	------	------	268	7.1
1,000	281	9.1	257	2.3	239	10.5	248	5.3	74	5.4	162	5.1	256	9.2	------	------	283	2.2	274	5.7	197	4.3	212	5.1	285	9.8
1,500	292	10.6	265	1.9	260	10.2	251	6.7	86	2.9	225	6.2	255	10.2	173	5.1	269	4.1	280	7.5	200	3.9	235	6.0	290	11.4
2,000	279	9.1	285	1.6	262	11.8	267	7.3	153	0.7	230	5.5	252	9.9	195	4.5	287	5.1	290	9.1	204	4.8	240	6.4	288	13.2
2,500	284	10.7	330	4.2	262	12.3	285	8.8	295	2.8	246	4.7	262	7.0	243	3.3	280	7.5	287	11.1	191	5.2	244	6.4	291	12.8
3,000	282	9.9	313	3.5	282	10.3	286	9.5	295	3.6	256	4.8	276	9.5	258	5.0	287	7.7	290	12.2	198	8.5	252	6.5	299	12.0
4,000	------	------	------	------	272	11.9	253	10.1	282	8.3	------	------	------	------	250	8.1	285	10.2	299	15.6	------	------	263	7.9	------	------
5,000	------	------	------	------	------	------	------	------	------	------	------	------	------	------	249	10.6	289	12.3	------	------	------	------	------	------	------	------

[1] Navy stations.

TABLE 3.—*Maximum free-air wind velocities (meters per second), for different sections of the United States based on pilot-balloon observations during March 1938*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station
Northeast [1]	46.4	NW	2,260	21	Boston	40.4	WSW	3,050	31	Columbus	50.2	NW	9,520	28	Cleveland.
East Central [2]	36.0	WNW	1,360	1	Washington	46.4	WNW	4,680	8	Greensboro	34.6	NW	6,910	28	Cincinnati.
Southeast [3]	34.6	W	2,280	10	Charleston	35.8	W	4,260	10	Charleston	37.8	WNW	8,020	1	Jacksonville.
North Central [4]	32.7	SW	2,230	29	Bismark	36.4	WNW	4,790	13	Sault Ste. Marie	42.0	WNW	5,330	2	Sault Ste. Marie.
Central [5]	37.0	SSW	1,890	30	Moline	35.0	WSW	2,790	30	Moline	42.0	WNW	6,930	23	Moline.
South Central [6]	49.2	WSW	1,730	14	Amarillo	50.2	W	4,090	12	Amarillo	46.3	WSW	6,750	6	Abilene.
Northwest [7]	31.1	WNW	1,310	29	Billings	36.8	NW	4,820	28	Medford	49.0	NW	5,900	28	Medford.
West Central [8]	44.3	SW	1,740	23	Winnemucca	43.5	W	3,580	23	Cheyenne	55.2	NNW	7,880	14	Modena.
Southwest [9]	47.8	W	1,940	19	Havre	70.0	WSW	4,700	4	Albuquerque	59.0	SW	5,000	4	Albuquerque.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

By BENNETT SWENSON

March 1938 was marked by abundant precipitation, considerably above normal, in practically all regions from the Appalachian Mountains westward, except in portions of the North-Central States, and by temperatures above normal in all sections of the country except the extreme western portion. The heaviest precipitation occurred in portions of California, the lower Ohio Basin, the middle and lower Mississippi Basin, except Louisiana, in Alabama, Mississippi, and portions of Texas, with the most severe floods occurring in these regions.

Atlantic slope drainage.—Floods in this region were light, with no damages of consequence and occurred only at a few scattered points as indicated below.

Mild temperature over the Connecticut River Basin from March 20–25, accompanied by moderate rains, reduced the snow cover existing at high elevations. The high rate of run-off and breaking up of the ice in the northern tributaries resulted in a rise in the Connecticut River, reaching flood stage, however, only at White River Junction, Vt., on March 24.

Other slight overflows occurred as follows: Susquehanna River at Oneonta, N. Y., on the 6th; Tioughnioga River at Whitney Point, N. Y., on the 18th; Saluda River at Pelzer, S. C., on the 17th; and the Savannah River at Clyo, Ga., on the 26th and 27th.

East Gulf of Mexico drainage.—Heavy to excessive rains which fell during the night of March 15–16 over the Conecuh and Pea River basins, caused a rapid rise to above flood stages in both the upper portions of the Conecuh and Pea Rivers on the 16th, and a slower rise in the lower portion of the Conecuh on the 19th. The Choctawhatchee River rose slowly throughout its reach but exceeded flood stage only in the lower portion, on the 21st.

Property losses in this flood are estimated at approximately $75,000.

Heavy rains over the middle and lower Tombigbee River basin on the night of March 15–16 saturated the ground and a series of rises began in that river from Cochrane, Ala., southward. Additional heavy rains on March 19–20 occurred over the Tombigbee and Black Warrior watersheds. As a result of these rains the Black Warrior overflowed its banks at Tuscaloosa, Ala., on March 20, and the Tombigbee exceeded flood stage from Demopolis, Ala., southward. The recurrence of heavy rains on March 23–24 and March 31–April 2 maintained high stages in the Tombigbee so that unusually heavy rains on April 6–9, averaging from 5 inches over the Black Warrior watershed to 13 inches or more in the lower Tombigbee, resulted in floods of considerable proportions.

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The report on this flood must necessarily be continued in the next issue of the REVIEW.

The Pearl and Pascagoula River systems were at unseasonably low stages during the first three weeks of March owing to the deficiency of precipitation during December, January, February, and the first three weeks of March. With the occurrence of heavy rainfall on March 19 there began a series of rises, resulting in severe flooding that continued into April. Report on this flood will be made in the April REVIEW.

Upper Mississippi Basin.—Minor floods occurred in the Wisconsin, Illinois, and Meramec rivers during the month. No damage of consequence has been reported from these floods.

Flood stage was exceeded in the Wisconsin River on March 19 at Knowlton, Wis., when a stage of 15.1 feet was reached. The Illinois River has been, near or slightly above bankful stage at some points since January 30, but since the only flood conditions of any consequence occurred after the close of March, a complete report of the Illinois River flood will be made later. The Meramec River reached flood stage at Pacific and Valley Park, Mo., on March 16–17, and was followed by a second overflow on March 31–April 2 when slightly higher stages were reached.

Missouri Basin.—Flood conditions prevailed near the mouth of the Yellowstone River and in the extreme upper Missouri on March 14, and from there moved slowly southward. A large ice gorge formed about 25 miles north of Bismarck on March 18 and 19, backing up considerable water, and caused damage estimated at about $100,000.

The breaking up of the ice gorge on the 19th caused a rise in the stages downstream. Fortunately no heavy rains occurred during the progress of the crest downstream and the only other river gaging station along the Missouri that reported flood stage, in addition to Bismarck, was Nebraska City, Nebr., where a stage of 16.6 feet, flood stage 15 feet, was reached on March 28. Some overflowing of lowlands along the river occurred but owing to the earliness of the season and to precautionary measures very little damage occurred.

A slight overflow occurred in the Floyd and Big Sioux rivers between March 2 and 23, but resulted in no damage of consequence.

Ohio Basin.—The most general flooding in the basin prevailed in the Wabash-White River basin, where a succession of rises occurred and in the Ohio River which was above flood stage from slightly above Evansville, Ind., to the mouth. The flooding in the Wabash River continued into April and a single report for the entire period will be made after the waters recede. The flooding in the Ohio was light and the damage was negligible.

Other light floods in the basin occurred at scattered points as shown in the table below, but were of little consequence.

White Basin.—A flood in the White River began on March 29 and continued into April. The damages in this flood approximate $17,000.

Arkansas Basin.—Floods in the Basin during the closing days of the month and the first three days of April were light and were limited to the North Canadian River in the vicinity of Oklahoma City, Okla., the Poteau and Petit Jean Rivers, and to the Arkansas River near the Arkansas-Oklahoma border. The only losses reported were in the Arkansas River and are estimated at about $6,500.

Red Basin.—The overflow in the Red River that began about February 18 in the upper portion, continued in the lower reaches until the third week in March. Losses from the high water were of a minor nature and levees were not taxed at any point below Shreveport, La. Backwater over the lowlands in the vicinity of Coushatta and Colfax, La., caused the evacuation of about 200 families. The evacuation was orderly, however, and there was little loss, and no crop damage occurred.

Heavy rains over the upper Red Basin on March 28–29 produced another rise in that river but as the flooding continued into April a report will be given in the next issue of the REVIEW.

Lower Mississippi Basin.—Heavy rainfall over the upper St. Francis Basin on March 14–15 caused moderate flooding. On March 29 heavy rainfall again occurred over the basin resulting in a second flood which was in progress at the close of the month.

The Tallahatchie River, which has been above flood stage at Swan Lake, Miss., since January 28, continued above flood stage throughout the month.

West Gulf of Mexico.—Floods in this area were confined largely to the Trinity River and consisted of two floods, one that began in the upper portion in February and reached the lower reaches the first part of March, and the other beginning in the upper portion near the close of the month. The damages in the second flood are estimated at about $50,000, in the Trinity River above Long Lake, Tex.

Colorado Basin.—Heavy general rains from February 27 to March 4 resulted in severe floods in the Verde, Salt, and Gila rivers, in Oak Creek, and several other small creeks and washes in Arizona. The total losses over the state from these floods are estimated at approximately $200,000.

Pacific slope drainage.—Unusually heavy rainfall occurred over southern California during the 5-day period from February 27 to March 3, exceeding all records over a large area, and resulting in destructive floods. A report on these floods will appear in the next issue of the *Review.*

Considerable flooding in the Kings, Kaweah, and Tula rivers in California during March resulted in losses estimated at more than $800,000.

The third major flood of the season occurred in the Sacramento Basin during March. The outstanding feature of this flood was the serious condition in the lower San Joaquin River. At Lathrop, Calif., the water was continuously above flood stage for 20 days, from March 7 to 26.

Continued high water in much of the Sacramento Valley caused heavy seepage through the levees generally. Considerable land was overflowed and resulted in damage estimated at more than $2,000,000.

A light flood occurred in the Willamette River Basin from March 17 to 25 resulting in a loss of approximately $9,000.

Table of flood stages during March 1938

[All dates in March unless otherwise indicated]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ST. LAWRENCE DRAINAGE					
Lake Huron					
Flint: Columbiaville, Mich.	Feet 8	19	20	Feet 8.4	19
Lake Erie					
St. Marys: Decatur, Ind.	13	15	20	17.5	18
		23	24	14.4	23
		31	(1)		
ATLANTIC SLOPE DRAINAGE					
Connecticut: White River Junction, Vt.	18	24	24	18.0	24
Tioughnioga: Whitney Point, N. Y.	12	18	18	12.2	18
Susquehanna: Oneonta, N. Y.	12	6	6	13.0	6
Saluda: Pelzer, S. C.	6	17	18	6.7	17
Savannah: Clyo, Ga.	11	26	27	11.0	26, 27

See footnotes at end of table.

Table of flood stages during March 1938—Continued

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
EAST GULF OF MEXICO DRAINAGE					
Apalachicola: Blountstown, Fla	15	20	20	15.0	20
Pea: Elba, Ala	30	17	17	35.0	17
Choctawhatchee: Caryville, Fla	12	21	24	13.0	22
Conecuh:					
River Falls, Ala	35	16	20	44.2	16
Brewton, Ala	17	18	24	20.7	21
Etowah: Cartersville, Ga	18	20	20	19.2	20
Cahaba: Centerville, Ala	23	20	21	25.4	20
		23	24	27.1	24
Black Warrior: Lock No. 10, Tuscaloosa, Ala	46	20	[3] 25	51.4	21
				53.0	24
Tombigbee:					
Gainesville, Ala	36	24	(1)	41.0	27
Lock No. 4, Demopolis, Ala	39	20	(1)	53.4	29, 30
Lock No. 3, Ala	33	15	(1)	----	----
Lock No. 2, Ala	46	21	(1)	----	----
Lock No. 1, Ala	31	20	(1)	----	----
Pearl:					
Edinburg, Miss	20	23	30	23.7	26
Jackson, Miss	18	20	(1)	----	----
Pearl River, La	12	(2)	5	13.5	Feb. 28, Mar. 1
		27	(1)	13.0	28, 29
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
Wisconsin: Knowlton, Wis	12	19	24	15.1	19
Illinois:					
Havana, Ill	14	(2)	5	(4)	----
		24	(1)	15.6	Apr. 1, 2
Beardstown, Ill	14	(2)	2	14.0	Feb. 28–Mar. 2
		24	(1)	----	----
Meramec:					
Sullivan, Mo	11	31	Apr. 1	12.6	31
Pacific, Mo	11	16	16	12.2	16
		31	(1)	15.0	Apr. 1
Valley Park, Mo	14	16	17	15.7	17
		31	Apr. 3	18.9	Apr. 1, 2
Missouri Basin					
Big Sioux: Akron, Iowa	12	4	5	12.9	5
		12	23	17.2	18
Floyd: James, Iowa	15	2	[3] 13	16.7	2–3
Missouri:					
Bismarck, N. Dak	19	19	20	20.5	19
Nebraska City, Nebr	15	25	29	16.6	28
Ohio Basin					
Allegheny:					
Lock No. 8, Mosgrove, Pa	24	7	7	24.0	7
Lock No. 5, Schenley, Pa	24	7	7	24.0	7
Walhonding: Walhonding, Ohio	8	15	17	10.0	15
Tuscarawas: Coshocton, Ohio	11	15	20	13.4	18
Muskingum: Lock No. 7, McConnelsville, Ohio	22	17	17	22.2	17
Scioto:					
La Rue, Ohio	11	6	6	11.2	6
		15	17	12.1	15
Prospect, Ohio	10	16	18	10.8	17
Circleville, Ohio	14	17	18	15.0	17
Chillicothe, Ohio	16	16	18	17.6	16
Miami: Middletown, Ohio	15	16	16	15.0	16
Green: Lock No. 2, Rumsey, Ky	34	16	22	35.7	19–20
West Fork of White:					
Anderson, Ind	8	6	(1)	13.8	31
		7	10	21.0	7
Elliston, Ind	18	14	22	25.7	17
		[3] 25	(1)	23.4	28
Edwardsport, Ind	12	(2)	1	(4)	----
		6	(1)	19.0	18–20
East Fork of White:					
Seymour, Ind	14	15	19	17.5	17
		27	27	14.1	27
Williams, Ind	10	20	21	11.0	20, 21
White:		(2)	1	(4)	----
Petersburg, Ind	16	10	13	16.7	12
		14	(1)	22.6	21–23
Hazleton, Ind	16	10	(1)	23.7	23
Wabash:					
Bluffton, Ind	10	16	19	11.0	18
		31	(1)	----	----
Wabash, Ind	17	16	17	17.6	17
La Fayette, Ind	11	16	21	18.8	18
		25	26	11.8	26
Covington, Ind	16	17	22	22.5	19
		26	27	16.0	26, 27
Terre Haute, Ind	14	17	29	17.5	22
		30	(1)	----	----
Vincennes, Ind	14	19	(1)	15.7	27
Mount Carmel, Ill	19	19	(1)	21.65	23
New Harmony, Ind	15	20	(1)	17.2	26, 27
Cumberland: Celina, Tenn	28	6	8	30.4	6
French Broad: Oldtown (near Newport), Tenn	6	10	10	7.6	10
Ohio:					
Dam No. 47, Newburgh, Ind	38	17	25	39.5	21, 22
Evansville, Ind	35	17	26	37.3	22
Dam No. 48, Cypress, Ind	38	20	24	38.5	22
Mount Vernon, Ind	35	18	27	36.8	23, 24

Table of flood stages during March 1938—Continued

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
MISSISSIPPI SYSTEM—continued					
Ohio Basin—Continued					
Ohio—Continued.					
Dam No. 49, Uniontown, Ky	37	20	28	38.5	24
Shawneetown, Ill	33	14	Apr. 7	38.2	24, 25
				37.2	Apr. 4
Dam No. 50, Fords Ferry, Ky	34	13	Apr. 8	40.0	24, 25
Dam No. 52, Brookport, Ill	37	18	20	37.3	19
		31	(1)	----	----
Dam No. 53, Grand Chain, Ill	42	17	21	42.7	19, 20
		30	(1)	----	----
Cairo, Ill	40	16	22	41.1	19
		27	27	40.0	27
		30	(1)	----	----
White Basin					
Current: Doniphan, Mo	10	29	31	10.6	30
Black:					
Poplar Bluff, Mo	14	30	Apr. 2	15.8	31
Black Rock, Ark	14	(2)	10	(4)	----
		29	(1)	25.1	31
White:					
Calico Rock, Ark	18	29	31	20.9	29
Batesville, Ark	23	29	Apr. 2	31.1	30
Newport, Ark	26	31	(1)	----	----
Arkansas Basin					
North Canadian:					
Yukon, Okla	8	28	28	8.0	28
(East) Oklahoma City, Okla	14	28	28	14.7	28
Poteau: Poteau, Okla	21	29	Apr. 1	27.7	31
Petit Jean: Danville, Ark	20	29	Apr. 2	23.0	31
Arkansas:					
Fort Smith, Ark	22	30	Apr. 2	25.1	31
Van Buren, Ark	22	30	Apr. 3	25.4	31
Red Basin					
Little Missouri: Boughton, Ark	20	30	31	22.0	30
Ouachita:					
Arkadelphia, Ark	17	29	Apr. 1	22.7	29
Monroe, La	40	5	14	40.6	10
Little: Whitecliffs, Ark	25	31	(1)	25.3	31
Sulphur:					
Ringo Crossing, Tex	20	10	10	21.9	10
		27	(1)	26.1	29
Naples, Tex	22	30	(1)	----	----
Red:					
Index, Ark	25	31	(1)	----	----
Fulton, Ark	25	(2)	3	(4)	----
		31	(1)	----	----
Orand Ecore, La	33	Feb. 24	10	38.2	4
Alexandria, La	32	Feb. 22	16	39.8	8
Lower Mississippi Basin					
Big Lake Outlet: Manila, Ark	10	(2)	(1)	(4)	----
St. Francis:					
Fisk, Mo	20	16	20	23.2	18
		30	(1)	----	----
St. Francis, Ark	18	(2)	5	(4)	----
		21	28	19.8	23
Tallahatchie: Swan Lake, Miss	26	(2)	(1)	(4)	----
WEST GULF OF MEXICO DRAINAGE					
Elm Fork: Carrollton, Tex	6	28	(1)	12.4	29
Trinity:					
Dallas, Tex	28	28	(1)	38.8	30
Trinidad, Tex	28	29	(1)	34.8	31
Long Lake, Tex	40	(2)	8	(4)	----
Liberty, Tex	24	2	18	26.5	12
PACIFIC SLOPE DRAINAGE					
San Joaquin Basin					
San Joaquin: Lathrop, Calif	17	7	26	20.9	16
Sacramento Basin					
Sacramento:		17	17	23.0	17
Red Bluff, Calif	23	20	20	23.5	20
		23	24	27.6	24
Knights Landing, Calif	30	18	29	31.3	26
Columbia Basin					
Coast Fork: Saginaw, Oreg	9	19	19	11.7	19
McKenzie: Leaburg, Oreg	12	18	19	13.6	18
Santiam: Jefferson, Oreg	10	18	19	12.5	19
Willamette:					
Eugene, Oreg	12	19	19	13.2	19
Harrisburg, Oreg	10	17	[7] 21	14.0	19
		23	24	10.2	23
Albany, Oreg	20	20	21	22.5	20
Oregon City, Oreg	12	20	23	13.1	21

[1] Continued at end of month.
[2] Fell slightly below flood stage on the 23d.
[3] Continued from previous month.
[4] Crest occurred in February.
[5] Fell slightly below flood stage on the 11th.
[6] Fell slightly below flood stage on the 30th.
[7] Fell slightly below flood stage on the 18th.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, I. R. TANNEHILL in charge]

NORTH ATLANTIC OCEAN, MARCH 1938

By H. C. HUNTER

Atmospheric pressure.—Pressure averaged much higher than normal over waters adjacent to the southern portions of the British Isles and thence southward to the vicinity of the Iberian peninsula; and it slightly exceeded normal from latitude 45° southward over the central longitudes of the ocean, and over most of the region of the West Indies. A small deficiency appeared around Bermuda and thence northwestward to the coasts of New England and the Canadian Maritime Provinces. Near Greenland and Iceland a marked deficiency was recorded, being almost one-third of an inch at Reykjavik.

The extremes of pressure reported by vessels were 30.79 and 28.35 inches. The higher mark was noted on the 2d, about 200 miles to southwestward of the southwestern point of Ireland, by the Dutch motorship *Loosdrecht*. The lower mark was recorded on the American liner *Washington*, early on the 12th, near the southern tip of the Grand Banks.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, March, 1938*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.48	−0.19	29.94	13	28.62	2
Reykjavik, Iceland	29.36	−.32	30.06	12	28.67	22
Lerwick, Shetland Islands	29.75	+.05	30.51	12	29.26	16
Valencia, Ireland	30.19	+.29	30.71	2	29.57	20
Lisbon, Portugal	30.23	+.23	30.42	1, 4	29.80	21
Madeira	30.11	+.10	30.27	1, 2	29.77	20
Horta, Azores	30.23	+.05	30.54	1	29.80	10
Belle Isle, Newfoundland	29.84	+.01	30.38	17	28.68	1
Halifax, Nova Scotia	29.95	−.01	30.34	16	29.24	6
Nantucket	29.97	−.01	30.37	30	29.43	1
Hatteras	30.06	+.02	30.40	28	29.54	10
Bermuda	30.12	−.02	30.30	14	29.80	12
Turks Island	30.08	+.06	30.17	9	30.00	25
Key West	30.06	+.01	30.27	8	29.92	17
New Orleans	30.02	−.02	30.48	7	29.80	16

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—During the first half of the month the North Atlantic had weather as severe as during any previous part of the winter season of 1937–38. After the 15th there was decidedly less storminess except over the far-northeastern region. For March 1938, there were altogether from the North Atlantic 3 reports of winds of force 12, and 13 of force 11.

As the month began, an important storm was central over the Gulf of St. Lawrence, with a southward-extending trough. The American steamship *Excambion*, from Gibraltar for Boston, met force 12 west wind on the 1st, when in about the longitude of Halifax. This LOW center moved northward to southern Greenland by the late hours of the 2d.

Following this storm, another vigorous disturbance crossed the Virginia coast eastward on the 3d, and moved to the vicinity of the southern Grand Banks by the morning of the 5th; thereafter it advanced northward to unite with another system of low pressure. Numerous vessels reported intense gales in connection with this disturbance, though the highest force was only 11.

On the 9th, when a narrow trough stretched to southward from a LOW over southern Greenland, there was a 6-inch snowfall within two forenoon hours on the deck of the German liner *Hansa*, then west-bound, off the Grand Banks. The wind at the time of this snowfall was comparatively light.

A storm of marked importance was centered near Hatteras on the 10th, and traveled rapidly to the east-northeastward. Near the southern extremity of the Grand Banks, during the night of the 11–12th, the center of the storm deepened rapidly, and many vessels noted pressures lower than 29 inches, the barometer on the liner *Washington*, as already mentioned, reading 28.35 inches. Two American steamships, the *Swiftscout* and the *Black Condor*, had estimated force 12 winds in connection with this storm; and the American freighter *Aquarius*, bound from New Orleans to Liverpool, lost three members of her crew overboard, swept off the forward deck by an immense wave. Chart IX shows the situation on the 12th. During the 13th this storm became much weaker.

On the evening of the 12th a less important LOW center was north of Bermuda; it traveled eastward, at first nearly on the 40th parallel, then turned more to northward as it approached the longitude of the western Azores. Several vessels noted quite stormy weather in connection with this storm, which later united with the storm preceding it.

A LOW, central near Hatteras on the morning of the 18th, moved to near Sable Island on the 19th, and continued northeastward till it soon became part of a very large LOW system. Chart X shows the conditions on the 19th, when some vessels met strong gales in the area affected by this storm.

From the 21st to 25th there was very low pressure over most of the region from Iceland to the coast of Norway. Press reports indicate that winds of hurricane force were met not far from the Norwegian coast, and that many fishermen perished.

On the last day of the month a storm between Bermuda and the Azores developed considerable strength, and one vessel encountered force 11 wind late on the 31st, when nearly a thousand miles to east-northeastward of Bermuda.

Fog.—Over waters near the American coast from Texas to Cape Cod there was about as much fog during March as there had been during February; but from Cape Cod to northwestern Europe nearly all areas had a considerable increase in fogginess.

Again this month, there was no 5-degree square in North Atlantic areas which closely approached for number of days with fog the northwestern Gulf of Mexico, where 12 days had fog between 25° and 30° N., 90° and 95° W. Near and for moderate distances to eastward of Chesapeake and Delaware Bays there was fog on 8 days. Off New England and Nova Scotia fog was less prevalent than this, and was less frequent than is usual in March. In most of the Grand Banks area likewise fog was not so prevalent as usual during March, although the square 40° to 45° N., 45° to 50° W. is indicated as having 9 days, all of them either before the 9th or after the 18th.

Along the chief steamship lanes to northwestern Europe the portion between the 40th and 10th meridians had scarcely any fog before the 22d, but considerable afterward.

There was much fog at different times during the month over waters adjacent to the western coast of Europe and the British Isles. In the latter section the notable foggy periods seem to have centered around the 6th, 13th, and 23d; and there were at least 6 serious collisions, in which 3 comparatively small vessels were sunk, apparently without loss of life.

OCEAN GALES AND STORMS, MARCH 1938

Vessel	Voyage		Position at time of lowest barometer		Gale began March—	Time of lowest barometer March—	Gale ended March—	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Excambion, Am. S. S.	Gibraltar	Boston	42 10 N.	62 40 W.	[1]28	3a, 1	1	29.00	S.	W, 12	W.	W, 12	SW-W.
Bienville, Am. S. S.	Tampa	Manchester	42 00 N.	50 20 W.	[1]28	8a, 1	1	29.43	SSW.	S, 8	SSW.	SSW, 9	SSW-S.
Cities Service Kansas, Am. S. S.	Houston	Boston	40 00 N.	70 20 W.	[1]28	3a, 3	2	29.64	NNW.	NNW, 7	W.	NW, 9	
Cliffwood, Am. S. S.	Copenhagen	Portland, Me.	57 22 N.	19 08 W.	1	11a, 3	5	29.69	W.	WSW, 9	NW.	WSW, 10	SW-WSW.
Laurent Meeus, Belg. M. S.	Corpus Christi	Amsterdam	[2]37 17 N.	67 02 W.	3	1a, 4	4	29.49	SW.	SW, 8	NNE.	NNW, 9	SW-N.
Nishamaha, Am. S. S.	Galveston	Bremen	[2]40 06 N.	58 24 W.	3	2p, 4	4	29.42	NNE.	N, 11	NNW.	N, 11	SSW-N.
Pres. Roosevelt, Am. S. S.	New York	Hamburg	[2]41 21 N.	57 02 W.	4	3p, 4	5	29.46	NE.	NNE, 11	NNW.	NNE, 11	NE-NNW.
Silverwalnut, Br. M. S.	Colombo	Halifax	39 38 N.	56 02 W.	4	4p, 4	5	29.46	SSW.	SW, 10	N.	NNW, 10	SW-NNW.
Permian, Pan. M. S.	Beaumont	Havre	39 15 N.	56 28 W.	4	5p, 4	5	29.39	SW.	SSW, 10	NW.	SSW, 10	SSW-NW.
Lady Somers, Br. S. S.	Boston	Bermuda	[2]39 56 N.	68 27 W.	6	2a, 6	7	29.53	WSW.	SSW, 6	WSW.	WSW, 9	SSW-WSW.
Laurent Meeus, Belg. M. S.	Corpus Christi	Amsterdam	[2]41 53 N.	51 40 W.	6	4a, 7	7	29.74	SW.	SW, 6	SW.	SW, 9	SW-W.
Cliffwood, Am. S. S.	Copenhagen	Portland, Me.	51 47 N.	35 04 W.	7	2p, 7	7	29.56	S.	SW, 8	WSW.	SW, 9	SW-W.
W. C. Fairbanks, Am. S. S	New York	Smiths Bluff	34 25 N.	75 12 W.	10	Noon, 10	10	29.54	SSW.	WSW, 9	NW.	WSW, 9	SSW-W.
Gulf of Venezuela, Am. M. S.	Norfolk	Port Arthur	33 24 N.	75 28 W.	10	Noon, 10	10	29.67	SSW.	W, 8	W.	WSW, 9	SSW-W.
Bacchus, Du. S. S.	Maracaibo	New York	34 02 N.	74 55 W.	10	1p, 10	10	29.85	SW.	WSW, 11	N.	SW, 11	SW-WNW.
A. C. Bedford, Am. S. S.	Texas City	Boston	36 03 N.	73 33 W.	10	4p, 10	10	29.45	SSW.	N, 10	N.	N, 10	WNW-N.
City of Omaha, Am. S. S.	New Orleans	Havre	37 48 N.	68 48 W.	10	6p, 10	11	29.32	ENE.	NE, 9	NNE.	NE, 10	E-NE.
Swiftscout, Am. S. S.	Port Arthur	Bordeaux	[2]37 06 N.	65 17 W.	10	1a, 11	11	[2]28.95	ESE.	W, 8	N.	N, 12	WSW-N.
Belgian Gulf, Belg. M. S.	do	Antwerp	39 20 N.	62 10 W.	11	7a, 11	11	28.87	E.	N, 6	NNW.	NNW, 11	E-NNW.
American Banker, Am. S. S.	London	Boston	43 06 N.	51 09 W.	11	7p, 11	12	29.08	ENE.	N, 11	NNW.	N, 11	ENE-N.
Volendam, Du. S. S.	Rotterdam	New York	44 56 N.	46 24 W.	11	Mdt, 11	12	28.61	NE.	NE, 9	NW.	N, 11	NE-NW.
Steel Navigator, Am. S. S.	Gibraltar	Boston	38 28 N.	40 40 W.	11	2a, 12	12	[2]29.79	S.	S, 8	WNW.	S, 9	S-W.
Washington, Am. S. S.	New York	Cobh	[2]43 49 N.	46 39 W.	11	3a, 12	13	28.35	E.	NNW, 6	SW.	W, 11	ESE-Var-WNW.
Scanyork, Am. S. S.	Copenhagen	New York	48 06 N.	43 52 W.	12	Noon, 12	13	28.95	ENE.	NNW, 10	NW.	NW, 11	NE-NW.
Ile de France, Fr. S. S.	Havre	do	47 00 N.	36 55 W.	12	4p, 12	13	28.74	S.	SW, 11	WNW.	SW, 11	S-W.
Black Condor, Am. S. S.	Rotterdam	do	47 40 N.	37 35 W.	12	5p, 12	13	28.73	SE.	SSW, 11	WNW.	W, 12	S-WSW.
City of Omaha, Am. S. S.	New Orleans	Havre	39 50 N.	39 45 W.	12	2a, 13	13	29.40	E.	E, 10	NNE.	NNE, 11	E-NNE.
Swiftscout, Am. S. S.	Port Arthur	Bordeaux	[2]38 53 N.	59 11 W.	12	4a, 13	13	[2]29.00	SE.	NNW, 5	N.	N, 10	WSW-N.
Black Gull, Am. S. S.	Antwerp	New York	49 18 N.	25 00 W.	13	4p, 13	14	29.48	SSW.	WSW, 9	W.	W, 10	SSW-WSW.
Belgian, Gulf, Belg. M. S.	Port Arthur	Antwerp	41 07 N.	45 54 W.	14	2a, 14	14	29.27	NW.	NW, 9	NW.	NW, 11	SW-NW.
Vulcania, Ital. M. S.	Ponta Delgada	New York	37 46 N.	41 20 W.	13	3a, 14	14	29.68	SSE.	WSW, 10	NW.	WSW, 10	SSW-W.
Montgomery City, Am. S. S.	Colon	London	40 10 N.	39 19 W.	13	11a, 14	14	29.25	SSE.	W, 10	NNW.	NW, 11	WSW-NW.
Europa, Ger. S. S.	Cherbourg	New York	47 10 N.	38 24 W.	13	9a, 15	16	29.50	S.	SW, 7	NW.	W, 9	SW-NW.
Dordrecht, Du. M. S.	Liverpool	do	48 20 N.	34 10 W.	15	6p, 15	17	29.42	SSW.	SSW, 7	W.	WSW, 10	SSW-WSW.
Black Gull, Am. S. S.	Antwerp	do	46 36 N.	36 06 W.	15	4a, 16	16	29.40	SSW.	WNW, 8	W.	WSW, 9	W-WNW-WSW.
Berenice, Du. S. S.	Amsterdam	Pto. Colombia	38 25 N.	27 40 W.	18	Noon, 18	18	29.84	SW.	SW, 8	NW.	SW, 9	SW-S-NW.
Fluor Spar, Am. S. S.	Savannah	Liverpool	41 30 N.	56 08 W.	18	4p, 19	19	29.65	SSW.	S, 9	SW.	SSE, 9	S-SW.
Collamer, Am. S. S.	Bordeaux	New York	38 45 N.	58 45 W.	21	2p, 21	22	29.65	NW.	NW, 7	NNW.	NW, 9	WSW-NW.
Mormacsun, Am. S. S.	Copenhagen	Portland, Me.	56 52 N.	22 11 W.	24	2a, 24	24	29.60	W.	W, 8	WNW.	WNW, 9	
Ary Lensen, Br. M. S.	New York	St. Thomas	[2]37 01 N.	72 22 W.	26	7p, 26	26	29.93	WSW.	WSW, 8	NW.	NW, 10	SSW-NW.
Syros, Am. S. S.	Rotterdam	Tampa	35 40 N.	36 00 W.	30	4a, 31	31	29.61	SSE.	S, 8	SSW.	SSE, 9	SSE-SSW.
Laurent Meeus, Belg. M. S.	Lorient	Houston	[2]36 41 N.	48 15 W.	31	4p, 31	[4]1	29.55	N.	Var. —	N.	N, 11	ENE-Var-N.
Sundance, Am. S. S.	Antwerp	Jacksonville	46 17 N.	39 35 W.	31	10p, 31	[4]1	29.53	NE.	NE, 9	N.	NE, 9	NE-NNE.
NORTH PACIFIC OCEAN													
Steel Exporter, Am. S. S.	San Francisco	Honolulu	34 09 N.	132 42 W.	1	6a, 1	1	29.37	SE.	S, 8	W.	SSW, 9	SE-SSW.
Toho Maru, Jap. M. S.	Kure	Los Angeles	36 24 N.	132 24 W.	1	3p, 1	1	29.10		WSW, 10		WSW, 10	
Hiye Maru, Jap. M. S.	Yokohama	Vancouver	50 42 N.	166 42 W.	1	1p, 2	1	28.95		W, 6		NW, 8	NW-WSW.
Toorak, Br. S. S.	Shanghai	Los Angeles	40 11 N.	151 10 W.	3	Noon, 3	5	29.20	W.	WSW, 5	WNW.	W, 8	SW-W.
Jefferson Myers, Am. S. S.	Balboa	San Diego	15 30 N.	94 48 W.	6	6p, 6	6	29.85	NW.	NW, 7	N.	NW, 8	None.
Kahuku, Am. S. S.	Los Angeles	Balboa	14 30 N.	95 16 W.	6	3a, 7	7	29.89	NE.	NNE, 7	NNE.	NNE, 8	
Mauna Ala, Am. S. S.	Seattle	Honolulu	33 36 N.	142 36 W.	7	10p, 7	8	29.64	WNW.	WSW, 5	NW.	NW, 10	SE-WSW-NW.
Empress of Japan, Br. S. S.	Victoria, B. C.	do	35 40 N.	144 00 W.	8	2a, 8	8	29.74	NNW.	NNW, 7	NNW.	NW, 9	
Matsonia, Am. S. S.	Honolulu	Los Angeles	30 29 N.	133 11 W.	8	4p, 8	9	29.71	SSW.	SSW, 8	SSE.	WNW, 9	SSW-WNW.
Mana, Am. S. S.	Port Gamble	Honolulu	36 15 N.	140 48 W.	8	7p, 8	8	29.23	WNW.	W, 4	W.	WNW, 8	W-SW.
Otowasan Maru, Jap. M. S.	Los Angeles	Tokuyama	30 48 N.	140 06 W.	8	3a, 8	9	29.76	NW.	W, 5	NW.	NW, 8	S-W.
Mauna Ala, Am. S. S.	Seattle	Honolulu	32 12 N.	144 30 W.	8	Mdt., 8	9	29.62	NNW.	NW, 8	NNW.	NW, 9	WNW-NW.
Ward, Am. M. S.	Hong Kong	Los Angeles	33 18 N.	139 37 W.	8	3a, 11	10	29.84	NW.	N, 7	N.	N, 8	
Mauna Kea, Am. S. S.	Honolulu	do	27 23 N.	143 18 W.	9	4a, 10	10	29.88	NW.	N, 8	NNW.	NW, 8	NW-N.
Meigs, U. S. A. T.	do	San Diego	28 18 N.	136 54 W.	10	2p, 10	10	29.51		W, 8		W, 8	
Tampa, Am. M. S.	Hong Kong	Los Angeles	21 58 N.	117 22 E.	10	8p, 10	12	30.02		NE, 8	NNE.	NE, 8	
Pres. Jefferson, Am. S. S.	Victoria, B. C.	Yokohama	38 27 N.	144 25 E.	10	Mdt., 10	11	29.63	ENE.	NE, 9	NNW.	NE, 9	ENE-NNW.
Hikawa Maru, Jap. M. S.	Vancouver	do	51 30 N.	168 36 W.	10	1p, 10	11	29.92	WNW.	WSW, 5	W.	W, 9	WSW-WNW.
Bengalen, Du. M. S.	Manila	Portland, Oreg.	42 49 N.	139 51 W.	11	4a, 12	12	29.54	NW.	NNW, 7	NW.	NW, 9	None.
San Luis Maru, Jap. M. S.	Yokohama	San Francisco	40 30 N.	134 24 W.	12	8a, 12	12	[2]29.41	NW.	WNW, 7	WNW.	NW, 8	WNW-NW.
Hikawa Maru, Jap. M. S.	Vancouver	Yokohama	50 14 N.	179 18 W.	11	8p, 11	14	28.64	S.	SW, 9	W.	WNW, 11	SW-WNW.
Pres. Grant, Am. S. S.	Yokohama	Victoria, B. C.	50 06 N.	150 12 W.	11	8a, 13	14	28.97	S.	W, 9	WSW.	WSW, 9	None.
Bengalen, Du. M. S.	Manila	Portland, Oreg.	46 00 N.	125 40 W.	14	6a, 14	14	29.70	SSE.	SSE, 7	SSE.	SSE, 8	None.
Solana, Am. S. S.	do	San Francisco	41 20 N.	157 20 E.	14	11a, 15	15	29.52	ESE.	NE, 7	NE.	E, 8	ESE-NE.
Pres. Grant, Am. S. S.	Yokohama	Victoria, B. C.	49 10 N.	130 55 W.	15	7p, 15	16	28.42	ENE.	N, 5	WNW.	W, 9	NE-WNW.
Solana, Am. S. S.	Manila	San Francisco	45 46 N.	177 45 W.	19	10p, 19	21	28.65	ESE.	SSW, 8	NW.	W, 10	S-W.
Aobasan Maru, Jap. M. S.	Yokohama	Los Angeles	[2]46 30 N.	178 51 E.	19	4p, 20	22	28.78	E.	E, 5	WNW.	WNW, 9	E-NE.
Makiki, Am. S. S.	Seattle	Honolulu	43 12 N.	134 00 W.	22	3a, 22	23	29.36	WSW.	W, 7	W.	WSW, 9	S-W.
Pres. Jackson, Am. S. S.	Yokohama	Victoria, B. C.	46 28 N.	166 22 E.	23	2p, 24	25	29.93	NW.	WNW, 9	N.	WNW, 9	WNW-NNW.
Solana, Am. S. S.	Manila	San Francisco	44 25 N.	151 10 W.	23	6p, 24	24	29.67	SW.	S, 9	WSW.	S, 10	S-WSW.
Kaiyo Maru, Jap. M. S.	Kure	do	46 12 N.	178 18 E.	24	Noon, 24	24	29.60	N.	WNW, 5	N.	N, 8	
Michigan, Am. S. S.	Legaspi, P. I.	do	38 12 N.	178 36 W.	25	—, 25	25	30.37	NNE.	NNW, 7	NNE.	NNE, 8	NNW-NNE.
Athelprincess, Br. M. S.	Yokohama	Los Angeles	36 30 N.	155 30 E.	26	3a, 26	26	29.62	SSE.	SSE, 10	SW.	SSE, 10	SSE-S.
Pres. Jackson, Am. S. S.	do	Victoria, B. C.	50 04 N.	142 10 W.	29	8p, 29	30	30.03	SE.	SE, 8	SE.	SE, 8	None.
Arimasan Maru, Jap. M. S.	do	Los Angeles	46 41 N.	175 00 E.	30	4a, 31	31	29.39	SE.	SSW, 8	W.	SE, 8	S-SW.

[1] February [2] Position approximate. [3] Barometer uncorrected. [4] April.

NORTH PACIFIC OCEAN, MARCH 1938

By WILLIS E. HURD

Atmospheric pressure.—There was a distinct change in the pressure situation over the great central region of the North Pacific in March as compared with that in February. In the preceding month the barometer was abnormally high over the Aleutians and unusually low in the vicinity of Midway Island. In March the conditions were reversed, with the Aleutian LOW deeper than in any previous March since 1926. At Dutch Harbor at or near the average center of the LOW, the mean barometer, 29.49, was 0.21 inch below the normal. At Midway Island, near the average center of the North Pacific HIGH this month, the mean barometer, 30.22, with departure from the normal of +.15, was the highest of record for March since 1918.

Along the American coast, the pressure departure from the normal ranged from —.24 inch at Juneau to —.02 inch at San Francisco. To the southward of the 30th parallel, except in the neighborhood of Midway, the average barometer was close to the normal.

The lowest pressure reading of the month was 28.40, at Dutch Harbor on the 12th. An almost equally low reading, 28.42, was made aboard the American steamer *President Grant*, on the 15th, near 49° N., 131° W.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, March 1938, at selected stations*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.76	−0.39	30.22	6	29.42	24
Dutch Harbor	29.49	−.21	30.18	26	28.40	12
St. Paul	29.56	−.17	30.24	26	28.76	12
Kodiak	29.54	−.15	30.16	5	28.52	13
Juneau	29.67	−.24	30.35	29	28.86	18
Tatoosh Island	29.85	−.11	30.53	25	29.10	15
San Francisco	30.04	−.02	30.27	31	29.54	12
Mazatlan	29.91	−.01	30.02	8	29.86	25-27, 29
Honolulu	30.04	.00	30.19	14	29.83	26
Midway Island	30.22	+.15	30.39	15	30.00	4
Guam	29.86	−.04	29.92	1, 10	29.71	6
Manila	29.86	.00	29.92	31	29.80	12, 13, 22
Hong Kong	29.95	−.03	30.19	14	29.66	22
Naha	30.02	+.02	30.30	31	29.83	20, 23, 27
Titijima	30.03	+.03	30.27	1, 20	29.80	24
Tokyo	30.04	-------	30.27	20	29.53	24

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales.—Despite the presence of low pressure systems along the northern steamer routes throughout most of the month, the weather was not particularly stormy, and such gales as occurred were mostly local in nature and, except in one instance did not exceed 10 in force. To the westward of the 160th meridian of west longitude, scattered gales of force 8 to 10 were reported on some 10 to 12 days. Of these, one was a force-9 gale encountered on the 10th–11th to the near eastward of Honshu; six were force-8 to 10 gales met within the region 45°–50° N., 175° E.–175° W.; and the remainder were at widely separated points. On the 12th, when the lowest barometer of the month occurred at Dutch Harbor, only one ship reported a gale over the widely depressed area about the center.

The stormiest region of the ocean was that lying along the United States-Hawaiian routes. This area was affected not only by the cyclones that entered extreme northeastern waters from the westward, but by those that developed between or to the northward of the Hawaiian Islands and the coast of the United States. Of these middle-latitude cyclones, one appeared at some distance southwest of California on the 1st. It moved northeastward and affected Washington coastal waters on the 3d and 4th. Another formed near 30° N., 150°–155° W., on the 7th. It traveled eastward at first on an erratic course, then northeastward, and lay off the Washington coast on the 12th, entering it on the 13th. The earlier cyclone caused gales of force 8 to 10 along the middle half of the San Francisco-Honolulu route on the 1st, with pressure down to 29.10 inches, near 36½° N., 132½° W., as reported by the Japanese motorship *Toho Maru*. In the second cyclone, that of the 7th–12th, the heaviest gales, of force 10, occurred on the 8th, but others of force 8–9 were reported on the 9th and 12th, all within the region 27°–43° N., 130°–145° W.

Meanwhile, after the LOW of the 12th had entered Washington, low pressure continued off the coast for several days. The only ship to report a gale close to land during the period was the Dutch motorship *Bengalen*, which experienced a southeasterly wind of force 8 on the 14th, in 46° N., 125°40′ W. On this day, however, in a deep cyclone centered near 50° N., 149° W., the Japanese motorship *Hikawa Maru*, encountered the strongest wind reported for the month, a gale of force 11 from west-northwest, barometer 28.64. During the 15th and 16th this deep disturbance moved eastward and lay off the coast of Washington and Vancouver Island. On both these dates 68-mile wind velocities from the southwest for a 5-minute period were recorded at the Weather Bureau station, Tatoosh Island, lowest barometer 29.10 on the 15th. At sea no gales higher in force than 9 were reported on either date, and these at some distance from the coast; but pressures were lower than 29 inches on both dates, with the lowest barometer, 28.42, occurring late on the 15th near 49° N., 131° W.

Unsettled weather persisted off the northwest coast of the United States until the 24th, but no further gales were reported in the vicinity after the 16th until the 22d and 23d, when force 8 to 9 winds were experienced within the locality 40°–45° N., 130°–135° W.

Gales of the Tropics.—All the gales reported by ships in tropical waters were of anticyclonic origin. Of these, a northeast monsoon wind of force 8 was encountered at the south entrance of Formosa Strait on the 10th. Tehuantepecers of force 8 were reported in the Gulf of Tehuantepec, on the 6th from the northwest and on the 7th from the north-northeast.

Fog.—There was much less fog observed on the North Pacific in March than in the preceding month. Along the American coast it was reported on only two days: On the 1st, west of Lower California, and on the 23d, near Cape Corrientes. Between the Japanese Islands and longitude 160° E. fog occurred on 5 days, and northwest of Midway Island, on 2 days.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, March 1938*

[For description of tables and charts, see REVIEW, January, p. 27]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	63.7	+7.9	Evergreen	90	[1] 29	4 stations	23	[1] 1	6.36	+0.61	Brantley	12.39	Seven Hills	1.25
Arizona	49.6	−2.1	Benson	90	12	Bright Angel Ranger Station.	−5	31	2.20	+1.16	Junipine	8.05	Douglas	.29
Arkansas	60.3	+7.7	Magnolia	91	21	Mammoth Spring	20	[1] 1	6.02	+1.29	Higden	10.71	Magnolia	3.25
California	47.4	−3.9	Brawley	89	20	Twin Lakes	−16	17	8.33	+4.62	Elk Valley	32.26	Brawley	.15
Colorado	37.8	+3.2	Holly	82	16	Hermit	−24	6	2.17	+.86	Cumbres	13.44	Trinidad	.10
Florida	69.4	+4.1	2 stations	94	[1] 6	Quincy	31	2	1.87	−1.26	Mason	5.14	West Palm Beach	.12
Georgia	61.9	+5.6	4 stations	91	[1] 22	3 stations	18	1	3.71	−1.11	Cedertown	9.03	Brooklet	1.17
Idaho	35.5	−.2	Lapwai	67	12	Obsidian (near)	−28	22	3.40	+1.59	Deadwood	9.35	Challis	.41
Illinois	49.2	+8.4	5 stations	84	[1] 21	Freeport	7	6	5.61	+2.43	Casey	12.65	2 stations	2.69
Indiana	47.8	+7.1	Bluffton	87	21	Albion	12	1	6.32	+2.57	Martinsville	10.17	Whiting	2.79
Iowa	43.7	+9.2	Keosauqua	89	21	Cresco	0	6	2.35	+.62	Washington	4.82	Harlan	.22
Kansas	51.0	+7.4	3 stations	89	21	Oberlin	12	6	2.06	+.63	LaCygne	5.44	Elkhart	.35
Kentucky	53.7	+7.3	Pippapass	86	[1] 21	2 stations	11	1	6.29	+1.60	Fords Ferry	12.00	Jenkins	3.55
Louisiana	67.4	+6.7	Abbeville	90	27	Tallulah	26	1	3.81	−.90	Alexandria	8.61	Delta Farms	.80
Maryland-Delaware	46.9	+4.5	Cumberland, Md	88	2	Mt. Savage, Md	6	1	2.72	−.85	Friendsville, Md	4.61	Delaware City, Del	1.89
Michigan	36.3	+6.6	Milford	84	22	Deer Park	−21	3	2.76	+.65	Adrain	4.82	Standish	.73
Minnesota	34.9	+8.2	Austin	80	21	Roseau	−19	3	1.51	+.33	Duluth	2.91	Redby	.19
Mississippi	64.7	+7.7	2 stations	89	26	2 stations	24	1	6.03	+.29	Fruitland Park	14.58	Biloxi	.61
Missouri	53.6	+9.6	Louisiana	90	21	Goodland	14	1	4.98	+1.72	Morehouse	10.72	Grant City	1.20
Montana	33.0	+2.2	6 stations	72	[1] 16	Wisdom	−18	22	1.27	+.32	Hebgen Dam	4.87	Browning	.11
Nebraska	43.1	+6.6	Auburn	88	21	Mumper	1	6	1.42	+.32	Purdum	2.86	Aurora	.33
Nevada	38.4	−2.0	Las Vegas	82	16	Marlette Lake	−6	30	2.11	+1.12	Marlette Lake	9.52	Sulphur	.62
New England	34.2	+1.9	3 stations	81	[1] 22	First Conn. Lake, N. H.	−36	4	2.33	−1.03	Pinkham Notch, N. H.	4.39	Presque Isle, Maine	.77
New Jersey	43.2	+4.1	Canoe Brook	85	22	4 stations	−1	4	2.15	−1.63	Burlington	4.30	Tuckerton	.90
New Mexico	44.8	+1.0	Lovington	90	25	Selsor Ranch	−18	31	.85	+.10	Dulce	4.31	Columbus	.00
New York	37.1	+4.9	Dansville	85	22	Stillwater Reservoir	−34	4	2.45	−.60	High Market	5.61	Cairo	.89
North Carolina	55.5	+5.5	2 stations	89	31	Mount Mitchell	6	1	3.30	−.90	Andrews	7.65	Swansboro	.80
North Dakota	33.1	+9.3	Cooperstown	72	27	Willow City	−14	3	.59	−.18	Howard	1.69	Hettinger	.11
Ohio	46.1	+7.3	Wilmington	87	22	Jefferson	3	4	5.28	+1.86	London (near)	7.57	Sandusky	3.11
Oklahoma	58.1	+7.3	Pauls Valley	90	25	Hooker	20	19	4.25	+2.04	Miami	7.51	Boise City	.53
Oregon	38.8	−2.2	Triangle Lake	73	11	Chemult	−14	30	5.38	+2.59	Brookings	26.51	Umatilla	.55
Pennsylvania	42.7	+5.0	Sharon	87	22	Muncy Valley	−5	1	3.19	−.31	2 stations	5.89	Gouldsboro	1.36
South Carolina	60.3	+5.6	Trenton	90	[1] 22	Long Creek (near)	16	1	2.24	−1.66	Clemson College	7.06	Georgetown	.18
South Dakota	37.9	+6.7	Menno	84	27	La Delle	−16	6	1.23	+.11	Academy	2.85	Reva (near)	.10
Tennessee	56.8	+7.3	Milan	87	21	Gatlinburg	11	1	5.61	+.24	Waynesboro	8.73	New River	3.53
Texas	64.2	+5.7	Mission	100	30	Hereford	20	30	2.15	+.12	Denton	8.58	2 stations	.00
Utah	37.7	−.6	St. George	74	16	Silver Lake	−12	30	2.89	+1.46	Silver Lake	8.38	Manila	.27
Virginia	50.9	+5.1	Culpeper	89	22	Mountain Lake	10	1	3.03	−.68	Mendota	4.95	Staunton	1.50
Washington	40.9	−.5	Leavensworth	73	26	Bumping Lake	1	20	4.53	+1.04	Wynoochee Oxbow	19.95	Kennewick (near)	.67
West Virginia	48.3	+5.8	Institute	92	22	Rainelle	3	1	4.03	+.10	Pickens	7.75	Wardensville	1.65
Wisconsin	36.2	+6.8	3 stations	79	[1] 21	Long Lake	−22	6	2.59	+.83	Lancaster	5.87	Danbury	1.25
Wyoming	32.5	+2.7	Lowell	75	22	South Pass City	−25	22	1.31	+.14	Bechler River	10.17	Worland	.13
Alaska (February)	4.6	−2.3	2 stations	64	[1] 27	Fort Yukon	−64	7	2.03	+.13	Little Port Walter	30.28	Barrow	.04
Hawaii	70.7	+1.8	Honokaa	89	1	Kanalohuluhulu	44	[1] 4	11.80	+2.42	Pihonua	56.00	Lahaina	.15
Puerto Rico	72.3	−1.3	4 stations	91	[1] 2	Garzas	50	[1] 11	4.19	+.57	LaMina (El Yunque)	12.92	Mona Island	.00

[1] Other dates also.

TABLE 2.—*Climatological data for Weather Bureau stations, March 1938*

[Compiled by Annie E. Small, by official authority U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Mile*								*0–10*	*In.*	*In.*
New England							**36.4**	**+3.6**										**75**	**2.37**	**−1.1**										**5.8**		
Eastport	76	67	85	29.89	29.98	+0.05	29.1	+0.2	52	22	36	1	4	22	23	27	23	77	1.55	−2.3	15	11.9	nw.	36	e.	17	8	8	15	6.2	9.3	T
Greenville, Maine	1,069	4	41	28.86	29.98	----	23.6	----	54	23	35	−27	4	12	54	20	----	----	2.48	----	15	----	se.	----	----	----	----	----	----	----	29.9	3.0
Portland, Maine	103	82	117	29.86	29.99	+.03	33.8	+2.0	68	24	41	0	4	27	31	29	24	69	3.17	−.7	11	8.4	n.	15	n.	3	16	5	10	4.6	2.9	.0
Concord	289	54	72	29.67	29.99	−.01	35.6	+4.8	80	23	46	−2	4	25	49	----	----	----	2.07	−1.0	11	6.2	nw.	20	nw.	21	16	6	9	4.6	4.1	.0
Burlington	403	11	48	29.51	29.96	−.04	31.3	+2.2	73	23	41	−24	4	22	41	27	23	76	2.09	.0	15	10.5	s.	34	s.	30	11	5	15	6.2	10.7	.0
Northfield	876	12	60	29.00	29.98	−.02	30.2	+3.8	71	23	41	−20	4	20	41	26	22	77	1.72	−.8	13	8.5	s.	30	s.	26	10	6	15	6.5	7.3	T
Boston [1]	29	33	62	29.94	29.97	.00	39.1	+3.5	78	23	47	7	1	31	38	34	29	71	2.42	−1.2	10	12.6	w.	34	ne.	17	7	8	16	6.7	.3	.0
Nantucket	12	14	90	29.96	29.97	−.01	39.4	+3.9	63	21	46	11	1	33	29	37	34	84	3.53	−.2	11	16.7	sw.	38	ne.	3	12	4	15	6.2	.2	.0
Block Island	26	11	46	29.96	29.98	.00	39.2	+3.8	62	22	46	9	1	33	32	36	32	77	2.61	−1.2	12	17.8	sw.	42	nw.	1	13	6	12	5.2	T	.0
Providence	159	215	251	29.81	29.99	+.01	40.2	+4.5	77	23	49	7	1	31	38	35	30	72	2.39	−1.1	12	12.3	nw.	37	nw.	27	12	5	14	5.7	.8	.0
Hartford	159	66	100	29.83	30.01	+.02	40.8	+5.8	75	22	50	6	4	32	39	----	----	----	1.93	−2.0	12	9.7	s.	29	nw.	26	8	10	13	5.8	1.6	.0
New Haven	106	74	153	29.89	30.01	+.02	41.4	+5.6	72	21	50	8	4	33	35	36	30	68	2.57	−1.5	12	9.9	n.	29	sw.	2	8	10	13	6.1	1.5	.0
Middle Atlantic States							**46.8**	**+6.1**										**68**	**2.44**	**−1.0**										**6.3**		
Albany	97	97	112	29.89	30.00	−.01	39.4	+6.7	80	23	49	−3	4	29	43	33	26	64	1.63	−1.0	14	8.3	s.	25	s.	23	6	10	15	6.8	2.4	.0
Binghamton	871	57	79	29.04	29.99	−.03	40.8	+8.2	82	22	51	1	4	30	46	35	32	78	1.92	−.7	14	7.5	nw.	23	nw.	26	2	9	20	8.0	2.3	.0
New York	314	415	454	29.66	30.00	.00	44.2	+6.5	74	21	53	8	4	35	38	38	31	64	2.34	−1.3	12	15.7	nw.	43	nw.	27	6	13	12	6.1	1.1	.0
Harrisburg	374	94	104	29.60	30.01	−.02	44.6	+5.7	80	22	53	13	4	36	31	39	32	67	2.83	−.2	12	8.3	w.	27	w.	27	5	10	16	6.8	2.3	.0
Philadelphia	114	174	367	29.90	30.03	+.01	45.8	+5.0	79	22	55	13	4	36	35	40	32	64	1.83	−1.6	13	13.6	sw.	34	s.	23	8	9	14	6.0	1.9	.0
Reading	323	283	306	29.66	30.01	----	45.6	+5.6	83	22	55	10	4	36	35	39	32	65	2.45	−1.1	14	12.1	nw.	37	nw.	27	8	9	14	6.1	2.1	.0
Scranton	805	72	104	29.12	30.00	−.02	41.8	+6.1	82	22	51	5	4	32	41	35	28	63	1.50	−1.7	10	7.6	sw.	28	nw.	26	5	10	16	7.1	2.0	.0
Atlantic City	52	37	172	29.96	30.02	.00	44.0	+5.4	72	21	52	17	4	36	34	40	35	75	1.97	−1.6	15	17.7	s.	41	ne.	15	8	9	14	6.2	1.6	.0
Sandy Hook	22	10	57	29.98	30.00	----	42.8	+3.5	71	23	50	14	4	36	30	38	34	74	1.89	−2.2	13	14.7	sw.	36	nw.	27	9	8	14	5.8	.7	.0
Trenton	190	89	107	29.80	30.01	----	44.0	+4.9	79	22	54	9	4	34	37	38	31	65	1.59	−1.8	10	10.1	s.	28	w.	1	6	10	15	6.5	1.6	.0
Baltimore	123	100	215	29.89	30.02	−.01	49.2	+6.9	79	21	59	16	4	39	33	41	34	65	2.44	−1.3	15	10.8	sw.	36	sw.	1	9	7	15	6.4	4.8	.0
Washington	112	62	85	29.90	30.02	−.02	49.8	+7.2	85	22	60	20	4	39	35	42	35	65	2.23	−1.5	15	7.9	nw.	30	nw.	6	9	8	14	6.3	2.5	.0
Cape Henry	18	8	54	30.02	30.04	----	52.8	+6.2	85	31	62	28	1	44	29	47	43	74	3.71	−.2	8	12.4	sw.	40	n.	10	9	13	9	5.3	.0	.0
Lynchburg	686	144	184	29.30	30.04	−.01	53.6	+6.3	86	22	65	26	1	42	39	45	38	64	3.16	−.4	9	8.5	sw,	31	sw.	23	10	7	14	5.9	T	.0
Norfolk	91	80	125	29.95	30.05	+.02	54.6	+6.4	85	31	65	26	1	44	32	47	42	71	3.73	.0	9	10.9	sw.	29	e.	10	7	9	15	6.3	.0	.0
Richmond	144	11	52	29.89	30.04	.00	53.2	+6.0	85	31	65	24	1	41	34	45	39	69	3.57	−.1	12	9.6	sw.	31	w.	31	10	11	10	5.5	.0	.0
Wytheville	2,304	49	55	27.62	30.04	−.01	49.4	+7.1	76	22	60	20	1	39	41	42	37	69	2.67	−.8	14	7.6	w.	27	sw.	2	7	11	13	6.5	.0	.0
South Atlantic States							**60.2**	**+6.4**										**73**	**2.18**	**−1.6**										**5.4**		
Asheville	2,253	89	104	27.70	30.07	+.01	52.4	+7.5	80	22	64	20	1	41	36	45	40	73	4.20	+.2	15	9.5	se.	27	s.	13	9	8	14	5.9	.0	.0
Charlotte	779	63	86	29.22	30.06	+.01	57.4	+7.0	83	22	68	27	1	47	30	49	43	66	2.84	−1.3	11	8.4	sw.	24	sw.	3	6	10	15	6.6	.0	.0
Greensboro [1]	886	6	56	29.10	30.07	----	53.6	----	83	23	66	25	1	41	39	46	41	71	2.28	----	9	9.2	sw.	26	sw.	31	8	7	16	6.4	.0	.0
Hatteras	11	5	50	30.05	30.06	+.02	56.2	+4.2	75	22	63	33	1	50	22	52	50	84	3.30	−1.0	9	14.0	sw.	42	w.	10	12	8	11	4.9	.0	.0
Raleigh	376	103	140	29.64	30.04	−.01	57.2	+7.0	84	31	69	28	1	46	36	50	44	69	1.39	−2.5	8	9.8	sw.	27	n.	26	11	12	8	4.9	.0	.0
Wilmington	72	73	107	30.00	30.08	+.03	59.8	+6.5	79	31	70	30	1	50	29	53	50	79	1.98	−1.2	7	10.9	sw.	31	sw.	10	12	11	8	4.8	.0	.0
Charleston	48	11	92	30.04	30.09	+.03	63.2	+5.8	83	26	71	35	1	56	25	57	54	79	.33	−2.7	2	10.7	sw.	28	ne.	28	8	11	12	5.8	.0	.0
Columbia, S. C	341	70	91	29.69	30.07	+.01	61.6	+6.4	85	22	72	29	1	51	32	52	45	63	1.09	−2.3	8	9.4	s.	27	nw.	10	11	14	6	4.9	.0	.0
Greenville, S. C	1,039	139	----	----	----	----	56.4	+6.5	82	22	66	30	1	47	30	----	----	68	4.14	−1.0	15	----	sw.	----	----	----	5	13	13	----	.0	.0
Augusta	182	62	77	29.86	30.05	−.01	62.6	+6.6	86	22	74	32	2	51	39	54	47	66	1.96	−2.2	9	6.5	s.	23	w.	3	8	13	10	5.5	.0	.0
Savannah	65	73	152	30.01	30.08	+.02	65.7	+6.7	87	20	76	37	1	56	31	57	54	77	1.25	−1.8	5	11.6	s.	44	s.	16	8	14	9	5.2	.0	.0
Jacksonville	43	86	110	30.05	30.10	+.04	69.2	+6.6	87	27	79	43	1	59	28	60	57	77	1.55	−1.4	6	7.8	s.	23	w.	10	11	17	3	4.1	.0	.0
Florida Peninsula							**74.0**	**+4.1**										**77**	**1.05**	**−0.9**										**3.0**		
Key West	21	10	64	30.04	30.06	+.01	75.9	+3.3	86	17	81	60	13	70	19	69	66	79	1.50	+.1	2	9.8	e.	18	se.	29	20	10	1	2.6	.0	.0
Miami	25	124	168	30.06	30.09	+.01	74.3	+4.1	83	11	79	55	1	69	22	67	64	76	.34	−1.8	6	9.6	se.	24	nw.	17	22	7	2	2.9	.0	.0
Tampa	35	88	197	30.04	30.08	+.01	71.8	+5.0	87	28	81	52	1	62	25	63	60	77	1.32	−1.1	2	10.3	s.	30	w.	17	15	13	3	3.5	.0	.0
Titusville	43	5	36	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
East Gulf States							**64.7**	**+6.8**										**76**	**4.96**	**−0.2**										**5.9**		
Atlanta [1]	976	5	53	29.02	30.05	−.01	58.4	+6.4	84	30	70	27	1	47	37	51	46	73	5.98	+.7	13	9.3	s.	34	se.	16	8	6	17	6.3	.0	.0
Macon	370	79	87	29.67	30.06	.00	62.4	+5.7	86	31	74	30	1	50	41	55	51	72	4.02	−1.0	8	7.5	s.	24	nw.	19	7	13	11	5.6	.0	.0
Thomasville	273	49	58	29.79	30.08	+.02	66.6	+6.4	86	26	77	38	1	56	36	59	55	----	2.22	−1.9	4	----	s.	----	----	----	----	----	----	----	.0	.0
Apalachicola	35	11	----	30.04	30.08	----	66.7	+5.1	80	26	74	43	2	60	25	62	59	84	1.81	−2.4	1	8.5	s.	27	e.	28	12	8	11	5.3	.0	.0
Pensacola	56	149	185	30.00	30.06	.00	66.2	+5.9	77	30	71	41	7	61	25	62	60	84	1.62	−3.2	6	12.7	se.	40	s.	15	9	15	7	5.3	.0	.0
Anniston	741	9	----	----	----	----	60.6	+8.1	82	30	72	25	1	50	38	----	----	----	9.94	+4.3	9	----	se.	----	----	----	10	9	12	----	.0	.0
Birmingham	700	11	48	29.28	30.02	−.04	61.7	+6.3	82	26	72	29	1	52	32	54	49	71	9.05	+3.4	13	9.1	s.	26	se.	15	9	8	14	6.1	.0	.0
Mobile	57	86	161	29.98	30.04	−.02	67.2	+7.5	81	26	75	41	7	60	27	62	59	82	2.15	−3.8	9	10.4	s.	26	s.	16	7	11	13	6.2	.0	.0
Montgomery	218	92	105	29.81	30.06	.00	65.2	+7.4	84	29	76	35	7	55	34	57	52	70	5.97	.0	8	8.0	s.	29	n.	19	9	9	13	6.0	.0	.0
Corinth	469	6	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Meridian	375	67	92	29.61	30.01	−.04	65.1	+8.0	85	21	75	34	1	55	35	57	53	72	9.69	+4.5	9	7.8	s.	23	sw.	13	11	6	14	5.7	.0	.0
Vicksburg	247	82	102	29.72	29.98	−.06	66.2	+7.7	83	26	75	37	1	57	28	58	53	69	6.15	+.6	11	9.9	s.	25	sw.	5	8	8	15	6.4	.0	.0
New Orleans	53	76	84	29.97	30.02	−.02	70.4	+7.6	85	26	78	45	1	63	25	64	60	78	.91	−3.8	6	8.1	se.	28	sw.	23	7	10	14	6.3	.0	.0
West Gulf States							**65.9**	**+6.7**										**72**	**3.41**	**+0.5**										**5.6**		
Shreveport	249	92	227	29.68	29.95	−.07	66.3	+8.0	86	4	76	39	1	57	32	58	52	67	4.95	+.8	9	12.7	s.	43	w.	22	9	10	12	5.5	.0	.0
Bentonville	1,303	12	38	28.57	29.92	−.09	56.2	+8.9	81	14	67	24	6	46	34	----	----	----	5.01	+1.0	13	9.5	s.	30	sw.	30	8	11	12	----	.0	.0
Fort Smith	463	57	82	29.45	29.93	−.08	60.2	+7.6	84	4	71	31	6	49	39	51	44	62	3.38	+.4	11	7.4	e.	29	sw.	13	11	10	10	5.1	.0	.0
Little Rock	357	94	102	29.57	29.94	−.09	60.6	+7.6	84	4	70	33	1	51	34	53	47	66	7.18	+2.6	11	9.7	s.	31	w.	22	9	9	13	5.7	.0	.0
Austin	605	68	90	29.28	29.91	----	66.6	+5.9	88	4	77	41	6	56	36	59	54	69	1.57	−.7	7	8.8	s.	30	se.	9	13	7	11	5.0	.0	.0
Brownsville	57	88	96	29.81	29.87	----	74.2	+6.0	89	3	81	56	7	68	24	69	67	85	1.87	+.6	4	12.5	se.	36	se.	28	3	17	11	6.5	.0	.0
Corpus Christi	20	11	78	29.88	29.90	−.08	72.0	+7.0	88	15	77	52	6	67	23	67	66	86	.48	−1.1	5	13.0	s.	50	s.	9	3	10	18	7.4	.0	.0
Dallas	512	220	227	29.36	29.90	----	63.8	----	86	4	74	34	6	54	29	55	48	63	4.40	+1.5	6	13.9	s.	54	w.	28	12	12	7	4.8	.0	.0
Fort Worth	679	92	110	29.20	29.91	−.07	64.2	+6.5	87	25	75	34	6	53	32	----	----	----	3.89	+1.6	7	12.0	s.	36	s.	28	21	5	5	3.2	.0	.0
Galveston	54	106	114	29.90	29.96	−.05	67.8	+5.4	79	19	72	51	6	63	15	64	62	86	1.82	−.9	8	11.8	s.	30	s.	28	7	8	16	6.4	.0	.0
Houston	138	292	314	29.81	29.96	----	68.6	+5.3	82	3	76	44	6	61	23	----	----	----	1.71	−1.8	10	13.2	s.	38	se.	18	7	8	16	6.6	.0	.0
Palestine	510	64	72	29.41	29.94	−.06	65.8	+6.7	87	4	75	38	6	56	33	58	53	69	5.67	+2.2	10	9.2	s.	25	s.	28	13	7	11	5.1	.0	.0
Port Arthur	34	98	106	29.94	29.98	----	68.4	----	83	16	75	45	6	61	25	----	----	----	1.95	−1.3	9	14.4	s.	38	s.	28	5	13	13	6.5	.0	.0
San Antonio	693	242	301	29.19	29.90	−.08	68.3	+5.5	88	25	78	43	6	58	31	60	55	68	3.82	+2.0	7	11.8	e.	30	se.	25	10	7	14	5.5	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, March 1938*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Mile*							*0–10*	*In.*	*In.*
							51.6	+7.4										71	5.73	+1.5										6.7		
Chattanooga	762	71	214	29.22	30.03	−0.03	58.8	+7.6	83	30	68	29	1	49	31	51	45	66	6.08	+0.3	15	8.4	s.	29	nw.	5	6	6	19	6.8	0.0	0.0
Knoxville	995	66	84	28.96	30.02	−.04	57.0	+8.3	82	30	67	24	1	47	34	49	44	68	5.78	+.7	16	6.8	sw.	21	nw.	5	9	9	13	6.1	.0	.0
Memphis	399	78	86	29.54	29.96	−.08	60.6	+8.3	82	25	69	31	1	52	34	54	48	67	6.90	+1.6	10	9.7	sw.	30	sw.	29	7	12	12	6.1	.0	.0
Nashville	546	168	188	29.43	30.02	−.03	57.2	+8.0	80	15	67	26	1	47	37	50	45	70	4.78	−.3	14	11.7	s.	38	se.	29	7	8	16	6.5	.0	.0
Lexington	989	6					50.6	+6.9	81	23	62	20	1	39	35				5.56	+1.2	18										.0	.0
Louisville	525	188	234	29.41	30.00	−.05	52.4	+7.0	81	22	62	26	1	42	37	47	42	71	6.76	+2.4	16	12.4	s.	35	sw.	15	6	11	14	6.4	T	.0
Evansville	431	76	116	29.50	29.97	−.07	53.4	+7.5	78	21	63	27	1	44	35	47	42	70	4.69	+.5	13	11.1	s.	40	sw.	29	8	5	18	6.7	T	.0
Indianapolis	822	194	230	29.07	29.97	−.07	47.4	+7.4	79	22	57	25	4	38	35	42	36	70	7.93	+4.0	16	12.4	s.	31	s.	30	5	10	16	6.7	T	.0
Terre Haute	575	63	149	29.31	29.94		49.8		79	22	59	27	1	40	32	44	40	74	9.30	+5.5	18	11.4	s.	30	e.	15	7	9	15	6.6	T	.0
Cincinnati	627	11	51	29.30	29.99	−.06	49.1	+8.2	82	22	59	24	4	39	31	43	38	73	6.54	+2.6	20	9.7	sw.	32	se.	31	6	9	16	6.8	T	.0
Columbus	822	90	210	29.10	29.99	−.05	47.0	+7.9	82	22	57	17	4	37	32	42	37	73	4.32	+.8	16	11.5	s.	37	sw.	5	7	9	15	6.5	2.1	.0
Dayton	899	60	163	29.00	29.97		47.5	+7.0	82	22	58	19	4	38	31				6.28	+2.6	18	10.9	sw.	32	s.	19	8	8	15	6.5	.2	.0
Elkins	1,947	65	83	27.96	30.02	−.03	47.2	+7.2	79	22	58	15	1	37	47	41	36	73	4.39	+.6	20	7.2	w.	30	w.	23	3	6	22	7.9	.8	.0
Parkersburg	637	77	84	29.30	30.00	−.05	49.4	+6.6	83	22	60	22	4	39	36	44	39	73	3.42	−.1	19	7.1	se.	21	nw.	16	6	10	15	6.6	T	.0
Pittsburgh [1]	1,273	39	54	28.61	29.98	−.06	45.4	+5.8	82	22	55	16	1	36	33	40	34	72	3.21	+.2	17	12.2	sw.	34	nw.	27	4	11	16	7.2	.8	.0
Lower Lake Region							40.4	+7.6										73	2.94	+0.3										6.8		
Buffalo	768	243	280	29.10	29.95	−.07	37.8	+6.7	71	22	47	−1	3	29	35	34	30	76	1.84	−.7	14	17.6	sw.	52	sw.	2	5	7	19	7.1	3.0	.0
Canton	448	10	61	29.46	29.95		30.6	+2.9	74	22	40	−30	4	21	40	28	24	80	2.71	+.2	13	9.1	w.	29	w.	24	6	9	16	6.7	11.5	.0
Ithaca	836	77	100	29.05	29.98		40.2	+8.4	82	22	50	−3	4	30	36	34	29	69	1.12	−1.2	14	10.8	nw.	34	s.	23	3	10	18	7.4	1.1	.0
Oswego	335	71	85	29.58	29.96	−.05	37.5	+6.3	82	22	46	−6	4	29	39	33	28	73	2.29	−.3	19	11.2	se.	27	n.	3	5	5	21	7.7	4.1	.0
Rochester	523	86	102	29.38	29.97	−.05	40.4	+8.6	83	22	50	1	4	31	30	35	29	68	1.33	−1.4	14	10.0	w.	32	sw.	2	4	9	18	7.3	4.8	.0
Syracuse	596	65	79	29.33	29.98	−.04	40.2	+8.6	82	22	50	−4	3	31	40				2.02	−1.0	17	7.9	w.	29	sw.	23	3	7	21	7.8	9.1	.0
Erie	714	130	166	29.18	29.96	−.06	40.8	+7.3	82	22	50	1	4	32	36	36	31	72	2.96	+.3	17	15.5	w.	38	w.	27	6	10	15	6.5	1.1	.0
Cleveland	762	267	318	29.12	29.96	−.07	43.6	+9.0	83	22	53	8	4	34	36	39	34	72	3.52	+.8	15	17.1	s.	41	w.	27	7	12	12	6.3	.6	.0
Sandusky	629	5	67	29.26	29.95	−.08	44.6	+9.5	84	22	54	13	4	35	32				3.11	+.4	17	11.4	sw.	29	nw.	23	6	11	14	6.6	.7	.0
Toledo	628	79	87	29.27	29.96	−.07	43.7	+8.4	82	22	53	14	3	34	29	38	34	73	5.22	+2.7	15	11.5	w.	30	w.	7	10	12	9	5.5	.5	.0
Fort Wayne	857	69	84	29.02	29.96		44.0	+7.2	81	22	53	16	4	35	31	39	35	78	4.73	+1.5	14	11.2	w.	28	w.	31	5	8	14	6.0	.4	.0
Detroit [1]	626	5	78	29.25	29.94	−.09	41.6	+8.2	81	22	51	9	3	32	32	37	32	74	4.40	+2.0	16	12.5	sw.	37	sw.	31	6	12	13	6.2	2.4	.0
Upper Lake Region							36.2	+7.9										77	2.99	+0.8										5.7		
Alpena	609	13	89	29.23	29.91	−.12	32.6	+7.1	79	22	40	−1	3	25	40	29	25	79	2.37	+.4	16	11.5	nw.	30	sw.	31	8	12	11	5.7	5.1	.0
Escanaba	612	41	49	29.23	29.92	−.12	30.0	+5.8	54	28	39	−8	3	22	32	26	22	77	2.57	+.7	13	10.8	s.	32	n.	2	11	7	13	5.5	5.5	.0
Grand Rapids	707	70	244	29.15	29.93	−.10	42.1	+8.7	82	22	51	14	3	34	31	37	33	76	3.35	+.9	13	13.8	sw.	43	sw.	31	8	10	13	6.3	2.9	.0
Lansing	878	5	90	28.97	29.93		40.6	+8.4	81	22	50	12	4	31	33	36	33	81	3.36	+1.0	12	10.5	sw.	27	sw.	31	7	12	12	5.6	3.3	.0
Ludington	637	5	54	29.20	29.91		38.0	+7.9	72	21	46	6	3	30	33	34	29		3.41	+1.1	11		s.			14	8	9		2.7	.0
Marquette	734	44	69	29.07	29.89	−.15	33.0	+8.2	67	28	42	−1	3	24	31	29	25	78	1.95	−.3	12	8.6	nw.	34	sw.	31	8	13	10	5.6	7.9	T
Sault Sainte Marie	614	11	52	29.22	29.94	−.09	27.2	+5.6	58	30	36	−16	3	18	39	24	21	81	3.83	+2.0	18	8.1	se.	31	sw.	31	7	10	14	6.1	8.1	T
Chicago	673	7	131	29.19	29.93	−.10	45.0	+9.7	79	22	53	19	6	37	28	39	35	74	3.51	+.9	11	12.2	sw.	28	w.	31	8	10	13	5.9	2.8	.0
Green Bay	617	109	141	29.21	29.90	−.14	36.1	+7.5	69	30	45	3	3	27	29	32	28	76	2.32	+.3	11	12.4	sw.	35	ne.	2	12	5	14	5.9	4.4	.0
Milwaukee	681	97	221	29.16	29.90	−.13	41.3	+9.2	77	22	50	16	6	33	35	36	32	76	3.29	+.9	12	14.4	w.	39	w.	31	11	6	14	5.6	3.8	.0
Duluth	1,133	5	47	28.61	29.86	−.20	32.8	+9.1	64	28	42	1	6	24	31	27	22	74	2.91	+1.4	11	12.7	ne.	41	w.	31	13	10	8	5.0	6.1	.1
North Dakota							33.7	+11.3										72	0.67	−0.2										5.4		
Moorhead, Minn	940	50	58	28.83	29.87	−.21	34.8	+12.1	65	27	45	0	3	24	34	30	24	71	.46	−.6	7	10.0	s.	29	nw.	31	7	15	9	5.9	.7	T
Bismarck	1,674	8	57	28.04	29.86	−.20	34.4	+10.2	65	27	44	4	6	25	31	30	24	71	.58	−.3	4	10.0	w.	32	nw.	31	8	13	10	5.4	4.5	.0
Devils Lake	1,478	11	44	28.25	29.86	−.19	33.0	+13.2	65	27	43	−1	3	23	32	28	23	73	.51	−.3	4	10.2	nw.	26	nw.	31	6	16	9	5.8	.1	.1
Grand Forks	833	12	67																												
Williston	1,878	42	50	27.83	29.84	−.20	32.7	+9.8	64	28	41	5	8	24	27	29	24	74	1.12	+.4	9	9.2	sw.	30	w.	30	11	14	6	4.7	8.5	3.0
Upper Mississippi Valley							45.8	+9.5										70	4.52	+2.2										5.9		
Minneapolis-St. Paul Minn	919	105	208	28.86	29.86	−.19	38.0	+8.4	76	21	47	5	6	29	29	33	26	66	2.11	+.7	10	11.5	w.	35	nw.	31	12	9	10	5.3	6.2	T
La Crosse	714	11	48	29.11	29.90	−.14	40.4	+8.9	74	21	50	11	6	31	37	35	30	73	3.20	+1.6	12	6.5	s.	21	w.	22	11	8	12	5.5	4.8	.0
Madison	974	70	78	28.83	29.90	−.14	40.8	+10.2	74	21	50	12	6	32	32	36	31	74	2.09	.0	10	10.4	sw.	27	n.	3	10	7	14	5.9	2.9	.0
Charles City	1,015	10	51	28.79	29.90	−.15	40.2	+9.5	81	21	50	6	6	30	35	35	31	75	2.36	+.6	11	7.8	w.	24	sw.	31	8	8	15	6.2	3.6	.0
Davenport	606	66	161	29.24	29.91	−.12	45.8	+9.7	81	21	55	17	6	37	31	40	35	70	3.09	+.8	13	11.7	sw.	33	sw.	29	11	9	11	5.6	1.0	.0
Des Moines	861	5	99	28.96	29.88	−.16	45.8	+9.9	86	21	56	18	6	35	37	39	33	69	2.24	+.5	11	11.4	s.	36	nw.	22	9	10	12	6.1	T	.0
Dubuque	699	60	79	29.14	29.90	−.14	42.8	+8.8	81	21	52	8	6	33	36	37	32	69	3.73	+1.7	10	7.3	nw.	21	sw.	24	8	7	16	6.4	5.6	.0
Keokuk	614	64	78	29.24	29.90	−.13	48.4	+9.5	83	21	58	23	6	38	33	42	36	67	4.58	+2.2	14	9.3	sw.	26	sw.	29	10	6	15	6.2	T	.0
Cairo	358	87	93	29.57	29.95	−.09	56.4	+9.2	80	21	66	29	1	47	35	50	45	70	12.40	+8.6	14	11.3	s.	34	sw.	31	6	7	18	7.0	.0	.0
Peoria	609	11	45	29.25	29.92	−.11	47.4	+10.4	80	22	57	23	6	38	34	40	36	72	4.42	+1.7	15	8.9	s.	24	w.	31	11	7	13	5.0	T	.0
Springfield, Ill	636	5	191	29.24	29.92	−.11	50.5	+10.3	80	21	60	26	6	41	34	44	39	71	4.45	+1.3	15	13.5	s.	32	s.	29	11	6	14	6.0	.0	.0
St. Louis	568	179	303	29.31	29.92	−.11	53.7	+9.6	82	21	64	27	6	44	37	46	41	70	9.52	+6.1	13	14.2	s.	41	s.	30	12	5	14	5.5	.0	.0
Missouri Valley							46.8	+8.8										66	2.12	+0.2										5.8		
Columbia, Mo	784	6	66	29.06	29.90	−.13	52.8	+10.2	86	21	64	24	6	42	42				5.59	+2.6	11	9.8	s.	28	sw.	29	9	8	14	5.7	T	.0
Kansas City [1]	750	32	45	29.05	29.86	−.16	52.2	+9.5	81	21	63	25	6	41	40	45	39	65	3.06	+.5	11	12.3	sw.	35	sw.	29	7	12	12	6.0	.1	.0
St. Joseph	967	11	49	28.83	29.87		50.6		83	21	62	21	6	39	40	43	36	64	1.69	−.8	10	10.8	nw.	32	w.	30	9	12	10	5.4	T	.0
Springfield, Mo	1,324	98	104	28.48	29.89	−.13	54.4	+9.2	81	21	64	26	6	44	34	47	40	65	2.76	−.6	13	12.2	s.	31	sw.	29	13	7	11	5.2	.0	.0
Topeka	987	65	87	28.80	29.86		51.6	+9.0	86	21	63	24	6	40	39	45	39	68	2.20	+.1	9	11.4	s.	29	sw.	21	5	16	10	6.1	.1	.0
Lincoln	1,189	11	81	28.59	29.87	−.15	46.0	+8.5	80	21	56	20	6	36	33	40	33	66	1.70	+.4	8	11.2	s.	44	w.	21	8	9	14	5.9	T	.0
Omaha [1]	982	31	44	28.81	29.87	−.17	45.0	+8.0	82	21	55	20	6	35	35	39	32	68	.51	−.9	8	12.6	s.	38	nw.	22	7	9	15	6.5	T	.0
Valentine	2,598	47	54	27.15	29.90	−.13	39.6	+7.3	73	20	50	8	6	29	41	34	26	64	1.27	+.2	11	10.4	w.	30	nw.	31	5	11	15	6.1	4.6	.0
Sioux City	1,138	64	106	28.65	29.88	−.17	42.6	+9.9	72	12	52	15	6	33	42	37	30	67	.97	−.2	7	10.4	nw.	31	nw.	31	10	8	13	6.1	.6	.0
Huron	1,307	59	74	28.48	29.90	−.16	36.8	+7.9	69	17	47	4	9	26	36	32	27	70	1.47	+.6	9	10.2	w.	35	w.	31	10	13	8	5.4	11.8	T
Northern Slope							35.5	+3.6										65	1.10	+0.2										6.8		
Missoula	3,263	80	91				37.0	+1.4	62	27	45	21	2	29	30				.76	−.2	10	6.8	se.	34	nw.	16	1	3	27	8.5	3.5	.0
Havre	2,507	11	67	27.19	29.87	−.13	32.2	+5.1	66	27	43	−6	7	22	36	27	20	65	1.40	+.9	6	11.0	sw.	34	w.	19	8	12	11	5.8	17.7	9.8
Helena	4,124	85	111	25.64	29.90	−.11	33.0	+.6	58	27	41	10	29	25	24	28	21	60	.94	+.2	10	8.6	sw.	34	s.	18	2	9	20	8.0	14.0	2.8
Kalispell	2,973	48	56	26.79	29.89	−.10	34.4	+1.5	56	27	42	14	1	26	31	31	27	75	.94	.0	10	5.7	w.	24	w.	18	1	5	25	8.1	10.0	T
Miles City	2,371	48	55	27.31	29.84	−.18	37.0	+8.4	69	16	47	12	29	27	34	32	26	68	1.00	+.1	12	7.9	w.	31	w.	29	7	7	17	6.6	4.8	1.9
Rapid City	3,259	50	58	26.45	29.85	−.16	39.3	+6.7	66	12	50	16	5	29	34	34	27	66	.83	−.1	7	9.0	n.	41	nw.	31	8	14	9	5.6	1.4	.0
Cheyenne [1]	6,144	5	39	23.77	29.84	−.12	36.6	+3.5	64	20	47	17	5	26	36	30	23	61	1.33	+.3	12	16.2	nw.	53	w.	29	7	14	10	5.8	12.9	.0
Lander	5,352	60	68	24.46	29.84	−.15	34.0	+1.6	64	16	46	5	6	22	37	28	17	53	1.66	+.5	5	6.8	sw.	36	sw.	28	7	14	10	5.6	15.7	.0
Sheridan	3,790	10	47	25.93	29.87		36.8		71	16	49	17	30	25	46	31	23	64	1.00	−.2	10	6.7	nw.	32	nw.	19	8	9	14	6.2	8.3	.0
Yellowstone Park	6,241	12	46	23.70	29.96	−.06	28.0	+.8	54	27	37	2	22	19	39	24	20	71	1.48	+.5	15	9.2	sw.	34	sw.	16	2	6	23	8.0	17.9	2.0
North Platte	2,821	11	51	26.92	29.86	−.14	43.3	+6.7	74	20	55	17	6	32	42	36	28	63	.79	−.1	8	9.2	n.	27	n.	17	7	10	14	6.1	.7	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, March 1938*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	*%*	*In.*	*In.*		*Mile*								*0–10*	*In.*	*In.*
Middle Slope							**49.2**	**+5.9**										**58**	**2.28**	**+1.0**										**5.2**		
Denver	5,292	106	113	24.55	29.81	−0.14	42.6	+3.3	72	20	54	21	31	31	36	34	21	48	2.12	+1.1	16	9.1	s.	32	nw.	14	7	16	8	5.7	16.4	0.2
Pueblo	4,685	80	86	25.13	29.80	−.12	45.6	+4.0	75	24	58	18	6	33	43	36	23	46	1.32	+.7	10	8.8	nw.	41	w.	12	14	9	8	4.9	8.3	.0
Concordia	1,392	50	58	28.38	29.87	−.14	48.0	+7.0	85	21	59	24	5	37	37	42	36	70	1.17	−.1	7	10.4	n.	26	n.	25	13	7	11	5.3	.0	.0
Dodge City	2,509	10	86	27.22	29.83	−.14	49.6	+6.8	83	21	62	21	6	37	38	41	32	60	1.63	+.7	6	13.9	sw.	35	nw.	2	14	7	10	5.2	.1	.0
Wichita	1,358	85	93	28.41	29.85	−.14	51.9	+6.8	83	21	63	25	6	41	36	45	38	63	1.91	+.2	9	12.3	nw.	30	sw.	30	11	10	10	5.0	T	.0
Oklahoma City	1,214	10	47	28.58	29.86	−.12	57.4	+7.4	85	20	69	27	6	46	33	49	42	63	5.51	+3.5	8	11.5	s.	26	w.	9	9	12	10	5.1	.0	.0
Southern Slope							**59.9**	**+5.3**										**48**	**1.58**	**+0.7**										**4.2**		
Abilene	1,738	10	52	28.08	29.87	−.09	63.4	+6.9	92	25	76	34	6	50	38	51	40	52	4.36	+3.1	7	11.8	s.	29	s.	29	15	10	6	4.1	.0	.0
Amarillo	3,676	10	49	26.13	29.84	−.11	52.8	+5.9	82	24	66	29	6	40	40	41	28	46	1.24	+.5	6	11.4	sw.	36	w.	30	13	12	6	4.6	.1	.0
Del Rio	960	63	71	28.87	29.85	−.10	68.7	+5.2	92	4	80	47	6	58	33	58	50	58	.35	−.4	5	10.3	se.	31	nw.	28	13	10	8	4.8	.0	.0
Roswell	3,566	75	85	26.26	29.85	−.05	54.6	+3.3	86	25	70	30	28	40	47	42	25	38	.38	−.4	2	10.4	w.	37	w.	30	17	12	2	3.4	.0	.0
Southern Plateau							**49.4**	**−0.7**										**47**	**1.37**	**+0.6**										**4.2**		
El Paso	3,778	82	101	26.11	29.87	−.01	57.4	+1.6	84	25	71	33	6	44	38	43	25	32	.49	+.1	2	9.5	w.	27	w.	14	18	11	2	3.0	.0	.0
Albuquerque [1]	4,972	5	39	24.95	29.85	.....	46.2	+.3	80	25	61	20	31	32	49	36	24	46	.22	−.2	4	12.0	w.	42	e.	26	10	16	5	4.6	T	.0
Santa Fe	7,013	38	53	23.12	29.87	−.02	40.8	+1.1	67	25	51	15	31	30	31	32	21	49	.81	.0	6	8.1	n.	26	nw.	14	9	9	13	5.8	6.2	.0
Flagstaff	6,907	10	59	23.23	29.84	−.07	35.4	−.5	60	16	47	9	31	24	36	31	----	68	4.39	+1.8	12	9.8	sw.	30	sw.	25	8	10	13	----	9.0	T
Phoenix	1,107	39	51	28.77	29.93	+.02	59.4	−1.3	84	24	72	36	31	47	40	47	34	46	.89	+.2	3	6.7	w.	24	s.	3	11	13	7	4.6	.0	.0
Yuma	141	9	54	29.82	29.96	+.02	62.2	−1.9	86	24	75	40	31	49	38	50	36	43	.61	+.3	3	7.1	w.	28	nw.	13	19	8	4	3.0	.0	.0
Independence	3,957	5	26	25.89	29.94	.00	44.5	−4.0	72	16	56	23	22	34	36	36	22	---	2.18	+1.7	6	-----	s.	17	n.	25	12	7	12	----	.0	.0
Middle Plateau							**39.2**	**−1.5**										**63**	**1.68**	**+0.8**										**6.9**		
Reno	4,527	61	76	25.38	29.96	−.02	38.6	−2.5	56	27	48	19	21	30	29	33	27	65	2.06	+1.2	13	8.2	w.	34	sw.	16	4	12	15	6.5	1.5	.0
Tonopah	6,090	12	20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Winnemucca	4,344	18	56	25.52	29.95	−.06	37.3	−2.7	60	23	48	9	21	26	37	33	27	69	1.34	+.4	13	9.6	sw.	32	nw.	28	4	6	21	7.5	6.5	.0
Modena	5,473	10	43	24.49	29.86	−.10	37.9	−.3	60	11	50	15	31	26	34	32	24	61	2.20	+1.2	11	11.2	sw.	49	s.	20	7	8	16	6.6	5.9	.0
Salt Lake City [1]	4,227	32	46	25.62	29.90	−.08	40.0	.....	64	20	49	17	18	31	37	35	28	62	3.11	.....	10	11.2	se.	50	nw.	20	3	13	15	6.9	13.9	.0
Grand Junction	4,602	60	68	25.26	29.84	−.10	43.0	−.6	67	20	53	23	22	33	36	36	28	60	1.10	+.3	11	7.3	nw.	30	s.	20	4	11	16	6.8	1.4	.0
Northern Plateau							**41.3**	**0.0**										**66**	**2.06**	**+0.9**										**7.5**		
Baker	3,471	36	54	26.34	29.94	−.09	37.6	.0	56	27	46	15	21	29	28	34	30	74	1.13	.0	11	7.2	s.	23	sw.	16	1	6	24	8.5	6.6	.0
Boise	2,739	79	87	27.08	29.97	−.06	41.8	−.9	59	11	50	24	21	34	25	37	30	65	3.16	+1.8	15	7.4	se.	24	nw.	28	1	12	18	7.6	6.6	.0
Pocatello	4,477	60	68	25.35	29.92	−.09	36.8	−.6	56	16	44	12	22	29	28	32	26	67	3.11	+1.8	20	10.5	sw.	31	sw.	20	4	7	20	7.4	15.1	T
Spokane	1,929	101	110	27.82	29.89	−.12	41.1	+1.4	58	11	49	27	29	34	25	36	31	69	2.09	+.9	13	7.8	s.	24	sw.	18	1	11	19	7.6	3.6	.0
Walla Walla	991	57	65	28.84	29.91	−.11	46.7	+.6	69	27	55	31	20	38	29	40	33	62	1.34	−.3	16	7.2	s.	28	se.	22	4	10	17	7.3	.5	.0
Yakima	1,076	58	67	28.73	29.89	.....	43.6	−.5	66	11	53	24	21	34	29	36	30	60	1.52	+1.1	10	5.9	nw.	25	sw.	18	6	10	15	6.6	1.3	.0
North Pacific Coast Region							**45.7**	**+0.1**										**75**	**5.80**	**+1.6**										**7.7**		
North Head	211	11	56	29.68	29.91	−.10	45.4	+.2	61	10	50	33	20	40	21	43	40	84	5.51	.0	22	16.0	e.	66	s.	15	6	8	17	7.2	T	.0
Seattle	125	90	321	29.75	29.88	−.11	46.4	+1.5	61	10	53	34	29	40	22	42	37	70	3.42	+.4	17	10.8	se.	48	sw.	18	4	7	20	7.4	T	.0
Tatoosh Island	86	10	54	29.75	29.85	−.11	44.8	+1.9	55	1	48	35	28	41	13	42	38	79	8.30	+.4	19	16.7	e.	68	sw.	16	6	6	19	7.2	.1	.0
Medford [1]	1,329	29	58	28.56	29.99	.....	44.5	−2.4	63	9	54	26	31	35	33	40	35	73	3.34	+1.6	18	-----	sw.	-----	-----	-----	2	8	21	8.0	4.1	.0
Portland, Oreg	153	68	106	29.76	29.92	−.10	47.0	+.1	69	11	53	34	31	40	24	43	38	73	6.42	+2.5	20	6.6	se.	24	s.	1	2	6	23	7.8	.7	.0
Roseburg	510	45	76	29.41	29.97	−.07	46.2	−.9	67	11	54	31	31	38	30	42	37	73	7.78	+4.5	20	5.4	s.	23	s.	2	0	8	23	8.5	4.8	.0
Middle Pacific Coast Region							**50.4**	**−2.3**										**71**	**8.97**	**+5.1**										**7.1**		
Eureka	62	73	89	29.97	30.04	−.02	48.2	−.1	62	10	54	35	30	42	18	45	42	79	13.97	+8.7	23	9.3	se.	32	n.	25	4	4	23	8.0	.0	.0
Redding [1]	722	20	34	.....	.....	.....	48.4	−5.6	74	27	55	33	22	41	26	43	36	66	12.27	+7.6	20	8.8	nw.	34	se.	12	3	6	22	7.9	1.2	.0
Sacramento	66	92	115	29.96	30.04	+.01	52.1	−2.2	72	27	60	34	30	44	28	47	41	68	3.92	+1.4	13	8.8	s.	29	nw.	25	9	8	14	5.9	.0	.0
San Francisco	155	112	132	29.87	30.04	−.02	52.8	−1.4	70	26	58	43	21	48	18	48	43	70	5.73	+2.6	18	9.4	w.	26	sw.	12	6	9	16	6.6	.0	.0
South Pacific Coast Region							**55.8**	**−0.6**										**67**	**5.62**	**+3.6**										**5.5**		
Fresno	327	97	105	29.69	30.06	+.05	52.4	−2.6	72	26	61	36	30	44	32	47	40	68	5.19	+3.6	14	7.0	nw.	26	w.	13	6	14	11	6.2	.0	.0
Los Angeles	338	159	191	29.65	30.02	.00	57.8	+.3	77	10	66	44	30	50	24	50	42	61	7.94	+5.2	9	7.3	sw.	23	nw.	17	11	14	6	4.5	.0	.0
San Diego	87	62	70	29.93	30.03	+.01	57.2	+.5	73	10	64	46	6	51	21	52	47	72	3.73	+2.0	10	8.1	w.	30	s.	2	8	12	11	5.8	.0	.0
West Indies																																
San Juan, P. R.	82	9	54	29.96	30.05	.....	74.6	−.8	84	12	78	67	11	71	17	-----	-----	---	4.09	+.9	16	15.3	e.	27	e.	8	15	16	0	3.7	.0	.0
Panama Canal																																
Balboa Heights	118	6	92	.....	[3]29.86	+.02	80.6	−.6	92	31	90	68	5	71	22	-----	-----	[2]72	.25	−.5	1	8.0	nw.	25	nw.	2	11	20	0	4.4	.0	.0
Cristobal	36	6	97	.....	[3]29.89	+.01	80.8	−.7	86	14	85	72	6	77	12	74	72	[2]75	1.68	+.2	9	14.3	n.	28	n.	14	11	17	3	4.5	.0	.0
Alaska																																
Fairbanks	454	11	87	[3]29.16	[3]29.70	.....	10.0	.0	53	1	26	−34	27	−5	50	10	4	67	.23	−.5	4	4.3	s.	15	sw.	23	12	6	13	5.1	3.0	16.1
Juneau	80	96	116	[3]29.58	[3]29.67	.....	36.2	+2.5	59	1	42	23	28	30	25	33	27	70	5.67	.0	17	6.8	se.	27	e.	25	7	4	20	6.9	8.3	.0
Nome	22	5	32	[3]29.61	[3]29.63	.....	11.1	+3.1	44	2	19	−31	23	3	35	12	8	76	.96	+.1	15	8.7	ne.	30	ne.	27	4	9	18	7.1	11.2	11.3
Hawaiian Islands																																
Honolulu	38	86	100	30.00	30.04	.....	73.3	+1.9	81	29	77	66	11	69	12	67	64	73	3.77	+.6	20	10.5	e.	30	ne.	8	4	11	16	6.7	.0	.0

[1] Observations taken at airport.

[2] Observations taken bihourly.

[3] Pressure not reduced to a mean of 24 hours.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, March 1938*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48	29.84	29.90	−0.01	23.9	−3.3	32.0	15.8	56	−10	2.94	−1.65	16.6
Halifax, Nova Scotia	88	29.69	29.96	+.04	28.8	−1.6	35.3	22.2	61	−2	3.51	−1.33	7.1
Yarmouth, Nova Scotia	65	29.85	29.97	+.03	31.2	−.8	38.1	24.3	48	1	4.43	+.32	27.6
Charlottetown, Prince Edward Island	38	29.89	29.97	+.06	21.9	−3.9	29.9	13.9	46	−12	2.79	−.87	13.6
Chatham, New Brunswick	28	29.84	29.95	+.03	22.0	−2.5	32.9	11.1	56	−21	.98	−2.37	4.8
Father Point, Quebec	20	29.91	29.93	+.01	22.6	−1.0	29.2	16.0	55	−14	.85	−2.07	3.3
Quebec, Quebec	296	29.64	29.92	−.04	24.0	+1.7	31.3	16.7	54	−13	3.34	+.14	20.2
Doucet, Quebec	1,236	28.54	29.94	−.02	15.1	+1.5	29.9	.3	62	−48	2.39	+.66	11.2
Montreal, Quebec	187												
Ottawa, Ontario	236	29.67	29.93	−.07	24.1	.0	33.1	15.1	57	−34	3.62	+.97	9.4
Kingston, Ontario	285	29.63	29.95	−.06	31.2	+4.0	38.3	24.0	61	−15	2.85	+.38	6.6
Toronto, Ontario	379	29.56	29.95	−.08	35.8	+6.0	44.1	27.4	73	−5	1.64	−.89	3.1
Cochrane, Ontario	930	28.32	29.89	−.17	20.6	+5.4	30.7	10.5	58	−36	1.57	+.27	5.6
White River, Ontario	1,244	28.50	29.90	−.14	21.8	+8.5	36.3	7.3	57	−47	1.47	−.03	5.7
London, Ontario	808	29.06	29.96	−.09	36.6	+6.8	45.9	27.3	75	2	3.70	+.78	5.2
Southampton, Ontario	656	29.20	29.93	−.06	32.8	+5.6	41.7	23.9	74	−11	2.62	−.06	3.2
Parry Sound, Ontario	688	29.22	29.93	−.09	29.4	+5.6	38.9	19.8	71	−19	3.88	+1.15	10.1
Port Arthur, Ontario	644	29.00	29.87	−.18	25.5	+5.2	36.4	14.6	56	−20	1.80	+.86	1.6
Winnipeg, Manitoba	760	29.00	29.85	−.19	28.2	+12.4	38.2	18.2	66	−12	.50	−.63	.5
Minnedosa, Manitoba	1,690	28.00	29.86	−.22	25.2	+10.2	34.6	15.7	62	−20	1.60	+.77	3.2
Le Pas, Manitoba	860	28.84	29.84	−.28	20.2	+9.2	30.1	10.3	46	−12	1.20	+.63	12.0
Qu'Appelle, Saskatchewan	2,115	27.52	29.86	−.22	27.6	+10.3	36.8	18.3	59	−6	2.45	+1.28	16.2
Moose Jaw, Saskatchewan	1,759	27.80	29.84	−.22	30.2	+10.4	39.0	21.5	64	−2	1.20	+.53	4.1
Swift Current, Saskatchewan	2,392	27.22	29.84	−.21	29.8	+8.2	37.5	22.2	63	6	1.21	+.46	11.9
Medicine Hat, Alberta	2,365	27.30	29.84	−.18	31.4	+3.5	40.5	22.3	62	0	2.55	+1.96	25.5
Calgary, Alberta	3,540	26.08	29.82	−.20	30.8	+5.7	39.7	21.8	56	6	.79	−.05	7.8
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	28.24	29.84	−.23	27.2	+13.2	35.4	18.9	55	−8	.64	−.26	5.2
Battleford, Saskatchewan	1,592	28.05	29.83	−.22	26.4	+11.3	36.0	16.9	58	−5	.70	+.17	7.0
Edmonton, Alberta	2,150	27.47	29.79	−.18	29.8	+7.5	38.4	21.3	60	2	.43	−.31	4.2
Kamloops, British Columbia	1,262	28.53	29.89	−.04	41.7	+3.8	50.3	33.1	64	25	.15	−.21	.0
Victoria, British Columbia	230	29.61	29.87	−.16	44.6	+1.0	50.3	38.9	57	32	2.62	+.24	T
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20	27.80	29.82	−.20	42.8	.0	48.8	36.7	57	30	11.62	+2.41	1.2
Prince Rupert, British Columbia	170	29.46	29.64	−.22	40.4	+1.4	46.9	33.9	66	27	4.68	−4.44	5.2
St. George's, Bermuda	158		30.11	+.03	63.1	+.3	68.3	57.9	74	50	2.78	−1.96	.0
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Cape Race, Newfoundland	99				19.9	−2.0	27.3	12.5	41	−6	4.09	+0.14	3.9
Father Point, Quebec	20	30.19	30.21	+0.25	12.8	+2.4	20.4	5.1	35	−10	1.62	−.34	16.2
Montreal, Quebec	187	30.00	30.23	+.20	17.2	+2.7	23.5	11.0	38	−5	3.36	+.19	18.8

TABLE 4.—*Severe local storms, March 1938*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as have been received concerning severe local storms that ocurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Fayetteville, Ark	4	11:30 p. m			$1,000	Heavy hail	Damage to windows, skylights, car tops, fruit trees, and gardens.
Sioux City, Iowa, and vicinity	4					Glaze	Streets and highways dangerous.
Sumner and Maury Counties, Tenn.	5	P. m				Thundersqualls	Several barns unroofed or demolished.
Irving, Ill	5				13,400	Electrical	Damage to lumberyard.
Kleberg, Nueces, and San Patrico Counties, Tex.	9	12:30 a. m	[1] 60		25,000	Straight-line winds.	4 persons injured; property damaged; path 100 miles long.
Salina, Kans., 2½ miles southeast.	10	6:30 p. m	100	0	2,000	Tornado	All buildings demolished and 17 members of 1 family injured, none seriously. Path 880 yards long.
Northdale, Colo	12	Midnight	33			Wind	Porch damaged; trees uprooted.
Cairo, Ill	13				1,000	Hail	Property damaged.
Cambria, Ill	13				5,000	Wind	Property damaged.
Columbia, Mo	13					Thunderstorm and heavy hail.	Fields washed; streets and cellars flooded; sewers inadequate. Water 4 feet deep in 1 underpass.
Washington, Nowata, Rogers, Tulsa, Creek, Wagoner, and Okmulgee Counties, Okla., portions of.	14	5:30–6:30 p. m.			97,000	Hail	Property and fruit trees damaged; some loss to crops, not estimated separately.
Okmulgee, Kellyville, Sapulpa, and Sand Springs, Okla.[2]	14			1		Tornado	A 45-minute rain preceded the twister and was followed by a hailstorm. Barn overturned and 3 small sheds unroofed.
Asbury, Iantha, and Liberal, Mo.	15	12:30 a. m	33	0	20,000	do	1 person injured; property and power lines damaged.
Verba, Miss., vicinity of	15	A. m	1,320	0	3,500	do	Property damaged; path 25 miles long.
Butler, Wayne, Cape Girardeau, and Perry Counties, Mo.	15	2:30 p. m	33-100	0	22,000	do	8 persons injured; property damaged.
Red Bud, Ill., 1 mile west	15	3:15 to 3:30 p. m.	167	0		do	Considerable damage to rural buildings, farm implements, and orchards. Loss to stock; path 3 miles long.

[1] Miles instead of yards.

TABLE 4.—*Severe local storms, March 1938*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Senath, Nesbit, Caruthersville, Liberty, Tywhappity, Hemphill, Bakersville, Bragg City, Wardell, and Swift, Mo.	15	3:25 p. m.	200–440	10	$65,000	Tornado	This storm originated in northeastern Arkansas. Many persons injured.
Dell and Blytheville, Ark.	15	4:45 p. m.	200	0	100,000	do	29 persons injured; property damaged. Path 10 miles long.
Belleville to O'Fallon, Ill.	15	4:53 p. m.	167–333	10	1,000,000	do	65 persons injured; 60 local buildings, and a schoolhouse, closed for the day, demolished or badly damaged.
Arlington, Ky., vicinity of	15	5:08–5:30 p. m.	150	0	2,100	do	2 persons injured; path 6½ miles long.
Red Bud and Darmstadt, Ill.	15	6:15 p. m.	100	0		do	12 persons injured.
Alabama, north-central and west-central portions of the State.	15			2	100,000	Tornadoes and windstorms.	55 persons injured; property damaged.
Mount Carmel, Ill.	15				80,000	Hail	No details.
Vincennes, Ind.	15					Rain and hail	Excessive rain increased flood danger. Basements flooded. Hail damage to orchards severe. Amount of damage not estimated.
McPaul, Iowa	15		50		8,000	Tornado	School building wrecked; 14 pupils and the teacher escaped injury. Path 3 miles long.
Jones' Chapel, Miss.	15				2,000	Thundersquall	Property damaged.
Dent, Crawford, Washington, and Jefferson Counties, Mo.	15			1	150,000	Tornado	18 persons injured; property damaged. Path of storm varied considerably; greatest damage over a path of about 880 yards wide and about 10 miles long.
Hales Point to Dyersburg, Tenn., and vicinities.	15			0	25,000	do	Barns demolished and farm animals killed. Path of storm several hundred yards wide and 30 miles long.
Rustburg, Va.	17	12:30–1 p. m.			2,000	Thunderstorm and hail.	Most damage to small buildings; windows broken. Fisherman struck by lightning, fell overboard and drowned.
Pueblo and Baca Counties and vicinities, Colo.	21					Wind and dust	Practically every county east of the 105th meridian covered by the dust pall. A severe duststorm moved into the Pueblo district from a southwesterly direction. Business houses and homes filmed with powdery dust. Air travel discontinued, because of high wind and poor visibility. Highway traffic extremely dangerous throughout most of the day. In Baca County, the storm was violent at times with visibility reduced to 50 feet.
Witoka, Minn.	22	3 a. m.	[1] 10		10,000	Thundersquall and hail.	Several barns, windmills, and sheds wrecked; building unroofed, windows broken, wires and poles down. Path about 20 miles long.
La Crosse, Trempeleau, Clark, Wood, and Marathon Counties, Wis.	22	A. m.			204,000	2 windsqualls	First squall caused $34,000 damage in first 3 named counties; second squall $170,000 damage in 3 latter counties. No details.
Vaughn, Tex.	22	2 p. m.	[1] 5	0	10,000	Tornado	Property damaged; path 12 miles long.
Itasca, Tex.	22	3 p. m.	[1] 3			Heavy hail	Loss to crops and considerable damage to roofs and to car tops.
Iowa, northern portion	22				30,000	Tornadic winds	Some of the storms accompanied by hail and severe lightning. At Eagle Grove a grain elevator was destroyed. At Clarion and Belmont small buildings were damaged and barns unroofed. Near Clear Lake, a barn was struck by lightning and 13 horses burned. At Sheffield, a tile plant was damaged. At Denison, a storm of tornadic characteristics with hail blew out plate-glass windows. At Rockwell City, a wall of a school building was demolished and a grandstand unroofed.
New Orleans, La.	23	5–5:30 a. m.				Thundersqualls	A number of trees blown down; small buildings damaged.
Vandalia, Ill.	25				1,000	Hail	No details.
Mankins, Tex.	26	12:10 a. m.	250	0	30,000	Tornado	Do.
Wichita Falls, Tex.	26	12:20 a. m.	330		5,000	Wind	1 person injured; no details. Path 300 yards long.
Greenwood, Tex.	26	12:30 p. m.		0		Tornado	Barns unroofed; poultry houses demolished, and fences blown down.
Georgetown, Ky.	26				50,000	Wind	Damage confined to 1 business block, mostly to roofs, windows, and merchandise.
McMillan, Okla., vicinity of	28	3:30 a. m.	33	0	1,000	Tornado	A small home destroyed and several others damaged. Path 440 yards long.
Weatherford, Tex.	28	9 a. m.		0		do	Small damage reported.
Pirtle, Okla.	28	1:30 p. m.	35	0	650	do	Path 1,320 yards long.
Honey Grove, Tex.	28	3:30 p. m.	[1] 1	0	10,000	do	Property damaged.
Wilburton, Okla.	28	4:15 p. m.	440	0	20,000	do	9 persons injured; property damaged. Path 1 mile long.
Texarkana and Mandeville, Ark.	28	7:30 p. m.	100–200	4	20,000	do	17 persons injured; property damaged. Path 10 miles long.
Nevada County, Ark.	28	10–10:15 p. m.	200	0	85,000	do	65 persons injured; about 50 houses destroyed; path 15 miles long.
Butterfield, Ark.	28	P. m.		0	1,000	do	3 persons injured; house destroyed.
Hope, Ark., 6 miles south	28	do		0		do	9 persons injured; property damaged. Path narrow and short.
Maugansville to Tangier Island, Md.	28					Gale	Chimney of a greenhouse blown down in Maugansville with $500 damage; several fishing vessels blown on a sandreef off Tangier Island; a power boat wrecked while attempting a rescue; poles down in various sections of Anne Arundel County.
Port Arthur, Tex., western portion.	29	12:50 a. m.	20	0	10,000	Tornado	Property damage confined to dilapidated houses, sheds, board fences, telephone and power lines. Path 1½ miles long.
Ferriday, La., vicinity of	29	3:30 a. m.		4	5,000	do	9 persons injured; property damaged.
Montana, north-central and northeastern sections.	29–31			3		Blizzard	This storm considered the worst in the memory of old residents. Heavy snow, falling on the 29th and 30th, piled into deep drifts that blocked highway traffic. Rail traffic interrupted and air traffic at standstill because of poor visibility. Loss from freezing and smothering to livestock in scattered areas. 3 persons lost in the storm froze to death.
Conway and Faulkner Counties, Ark.	30	2–3 a. m.	150–200	1	14,000	Tornado	14 persons injured; property damaged; path 65 miles long.
Conway, Faulkner, and Van Buren Counties, Ark.	30	2:30–3 a. m.	200	0	10,000	do	14 persons injured; path 35 miles long.
Cleburne County, Ark.	30	4 a. m.	200	2	14,000	do	3 persons injured; church and store destroyed; other property damaged.
Lone Elm, Kans.	30	9:45 a. m.	100	1	500	do	Several small buildings damaged; woman killed when a brooder house was blown upon her. Path 1 mile long.
Washington County, Okla.	30	10 a. m.	100–400	0	25,542	do	Valuable oil property completely destroyed at Ochelata where $20,000 damage occurred, the path being 100 yards wide and about a mile long. In Oglesby the path was 400 yards wide. Small crop loss.
Columbus, Kans.	30	10:50–11:15 a. m.	133	10	575,000	do	150 persons injured; 180 residences, 88 buildings, and 45 garages demolished or badly damaged.
Columbia, Mo., to Callaway and Andrain Counties, to about 20 miles southwest of Palmyra, Mo.	30	11:36 a. m.–2 p. m.	440	1	120,000	do	18 persons injured; property damaged.
Shelbina, Mo., vicinity of	30	1:30–2 p. m.		0	4,700	do	6 persons injured; property damaged, $3,200; loss to crops, $1,500.
Dixie to Williamsburg, Mo.	30	3 p. m.	300–440	0		do	8 persons injured; damage estimated at several thousand dollars.
Kellerville, Rushville, Astoria, South Pekin, and Eureka, Ill., and vicinities.	30	3–5:20 p. m.		13	1,000,000	do	75 persons injured; property and trees damaged.
St. Charles, Mo., vicinity of, to Alton, Ill.	30	5:53–6:15 p. m.	500	0	25,000	do	2 persons injured; property damaged.
Cleburne County, Ark.	30	6 p. m.	200–425	7	80,000	do	96 persons injured; 53 homes destroyed; cattle killed; path 40 miles long.
Independence County, Ark.	30	6 p. m.	425	1	12,000	do	5 persons injured; 12 houses damaged; path short.
Alton to Litchfield, Ill., and vicinities.	30	6:15–6:45 p. m.	167–440	0	315,000	do	11 persons injured; more than 100 residences and several buildings damaged. At Bunker Hill, 4 of the town's 5 churches demolished.

[1] Miles instead of yards.

TABLE 4.—*Severe local storms, March 1938*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Butler County, Mo.	30	7:50 p. m.	100-440	4	$50,000	Tornado	20 persons injured; property damaged.
White County, Ark.	30	8 p. m.		0	5,000	do	12 persons injured; path narrow and about 5 miles long.
Gideon to New Madrid, Mo., and vicinities.	30	9-9:30 p. m.		0	20,000	do	2 persons injured. Damage at Gideon about $20,000 and at New Madrid several thousand dollars.
Lamar, Stockton, and Humansville, Mo.	30	11:50 - 12:30 p. m.	100-133	0	5,000	do	Damage estimated for Lamar only.
Green County, Ark.	30	P. m.		0	15,000	do	3 persons injured, church and 8 farm buildings wrecked; path 14 miles long.
Independence County, Ark.	30	do	300	0	15,000	do	17 persons injured; 2 churches, 6 homes, and a store destroyed; path 12 miles long.
Minturn, Ark.	30	do		3		do	Property damaged; path short.
Randolph County, Ark.	30	do		0		do	Several farm houses wrecked; path 16 miles long.
Glen Carbon to Edwardsville, Ill., and vicinities.	30		200-880	0	75,000	do	3 persons injured; rural buildings and orchards damaged; loss to livestock.
Edwardsville, Greenville, Hardin, and Payson, Ill.	30				60,100	Hail	Property damaged; loss to fruit crop.
Hoopeston, Monticello, Mounds, and Venice, Ill.	30			1	19,000	Wind	Property damaged; in Venice 1 person killed.
Bardwell, Freedom, Irma, Marion, and Salem, Ky.[1]	30					Tornadic winds	Houses and barns demolished; livestock killed; 6 persons injured.
Henderson and Daviess Counties, Ky.	30				106,000	Torrential rains	Small streams swollen; livestock drowned. Damage to roads and bridges, $106,000.
McCracken, Carlisle, Livingston, and Crittenden Counties, Ky.	31				25,000	Wind	Property damaged.
Warroad, Minn., and vicinity.	31					do	Telephone and power lines damaged.
Grand Marais, Minn., and vicinity.	31					do	Considerable damage to the breakwater and to fishermen's property along the shore. About 30 cords of pulpwood, piled on the shore for shipment, washed into the lake by huge waves. Several streets flooded.

[1] From press reports.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, March 1938

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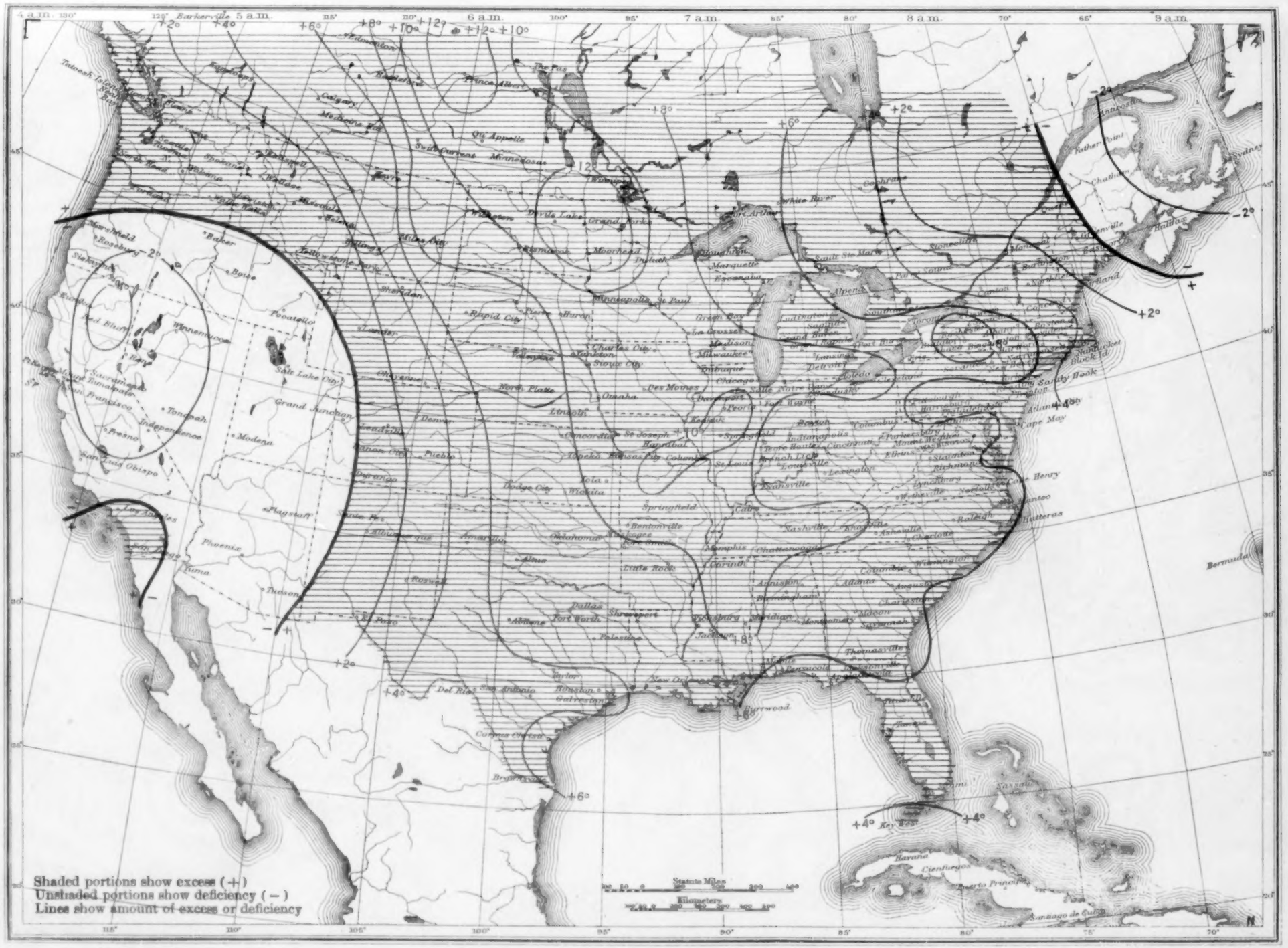
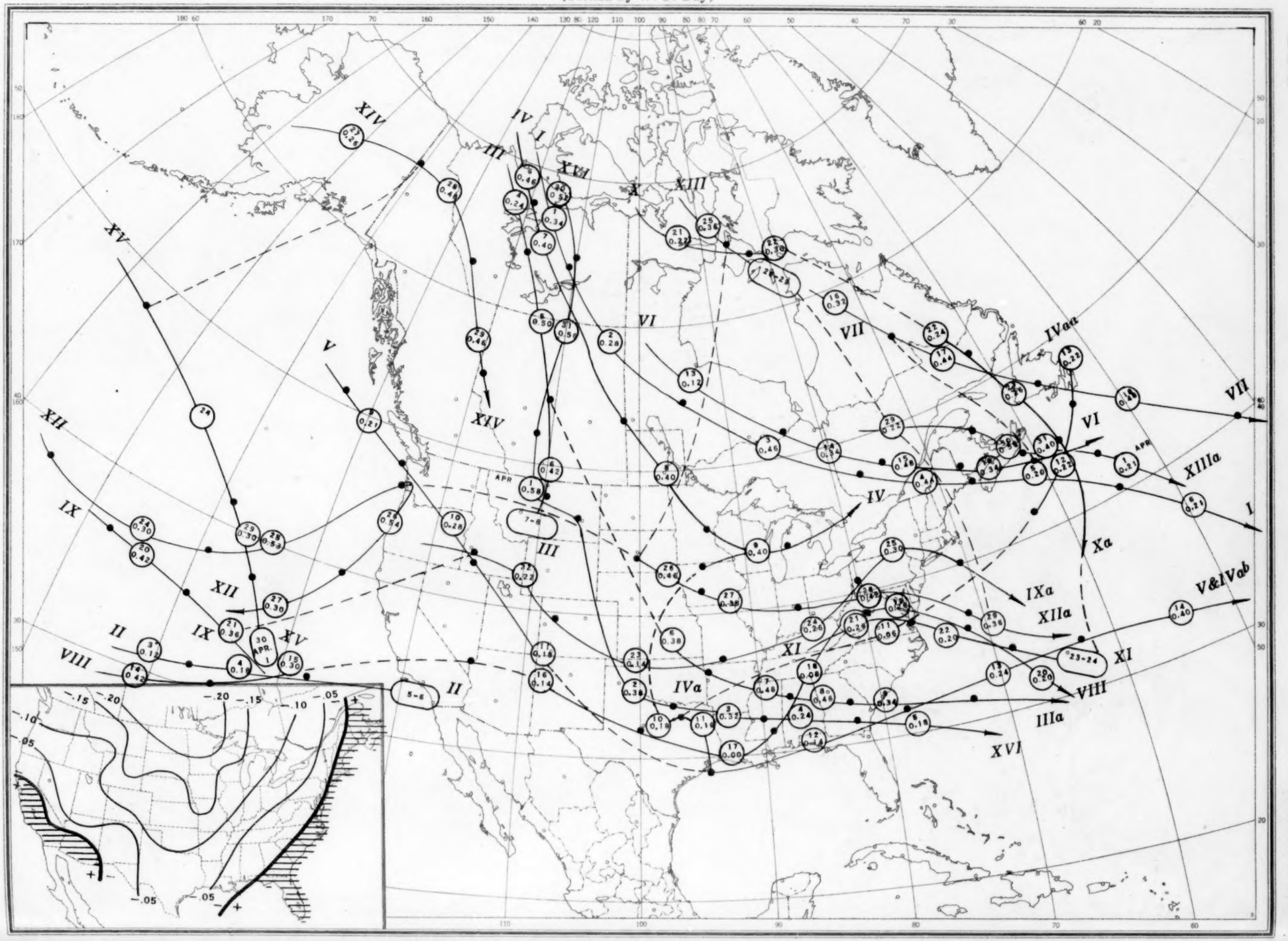

Shaded portions show excess (+)
Unshaded portions show deficiency (−)
Lines show amount of excess or deficiency
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, March 1938. (Inset) **Departure of Monthly Mean Pressure from Normal**

(Plotted by W. P. Day)



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

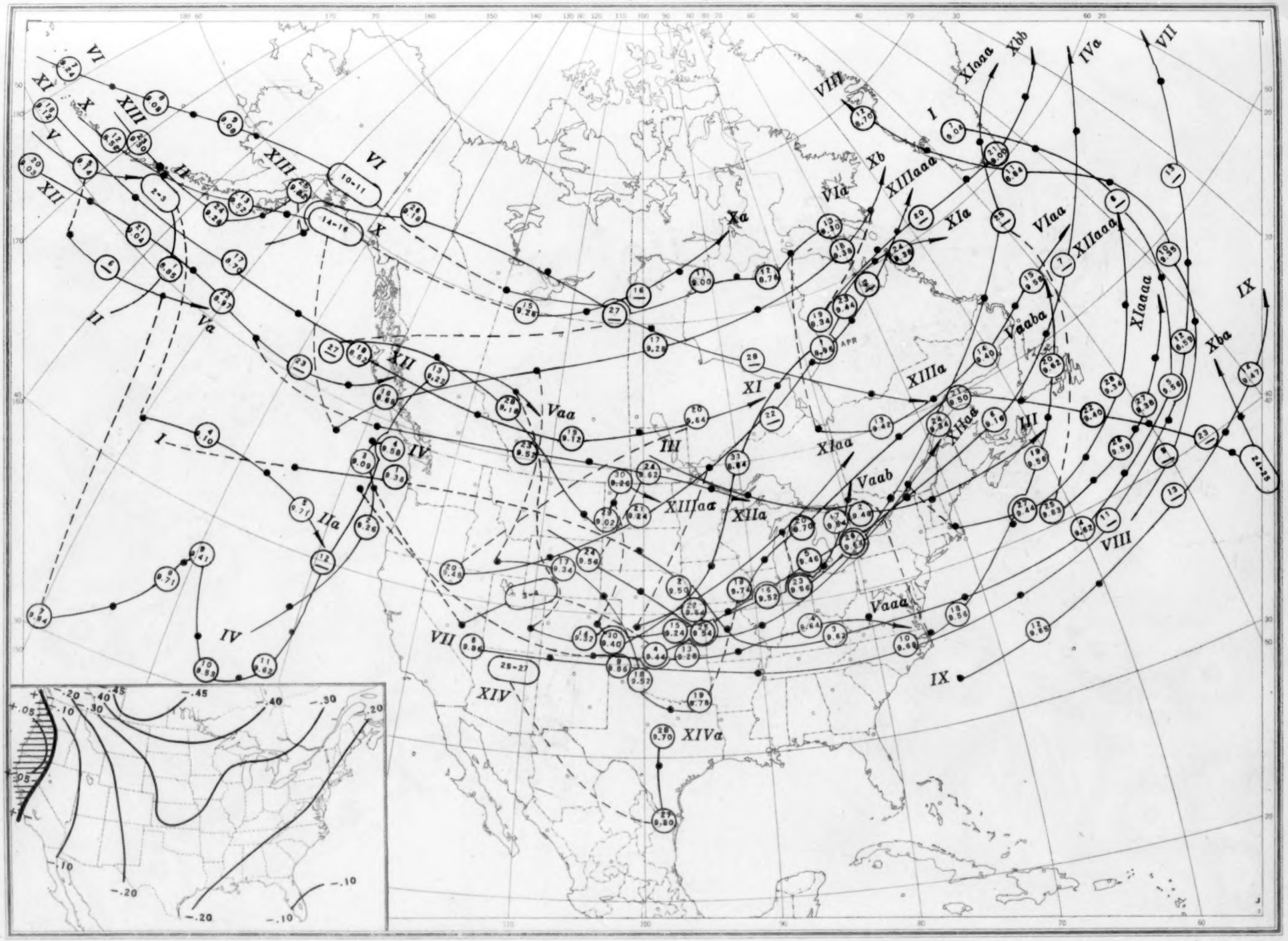
Chart III. Tracks of Centers of Cyclones, March 1938. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by W. P. Day)

Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, March 1938. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. P. Day)



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, March 1938

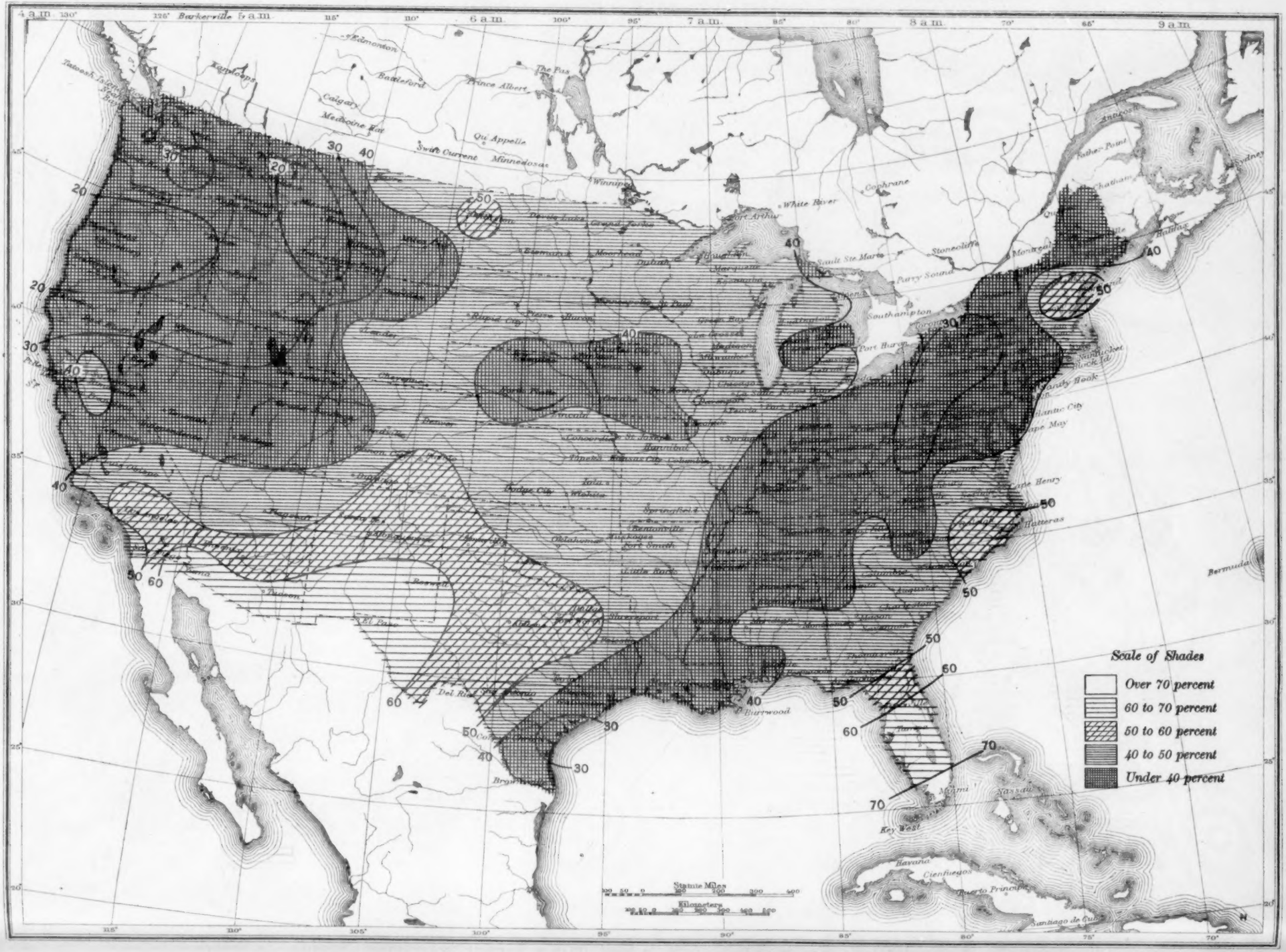


Chart V. Total Precipitation, Inches, March 1938. (Inset) Departure of Precipitation from Normal

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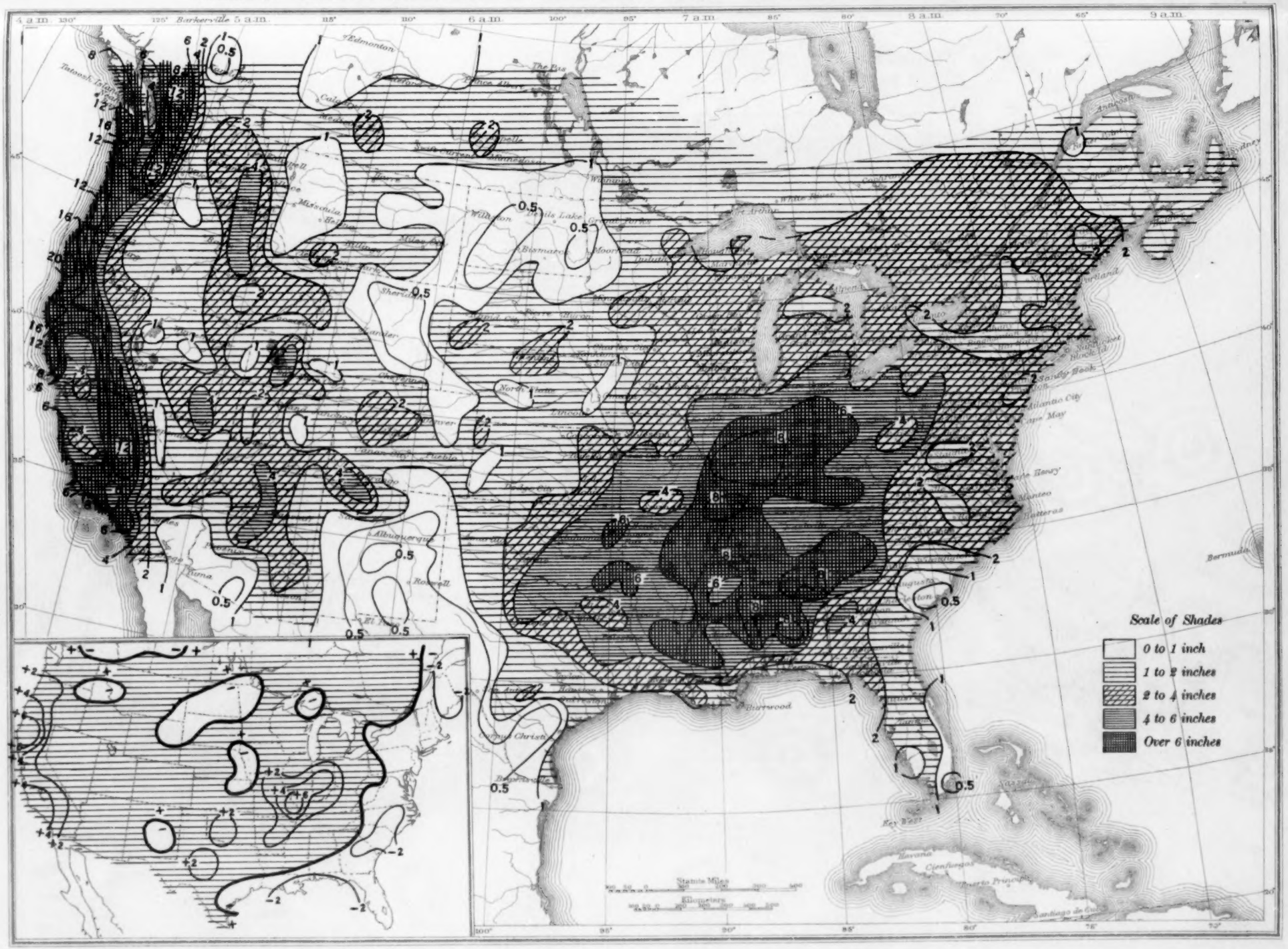

Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, March 1938

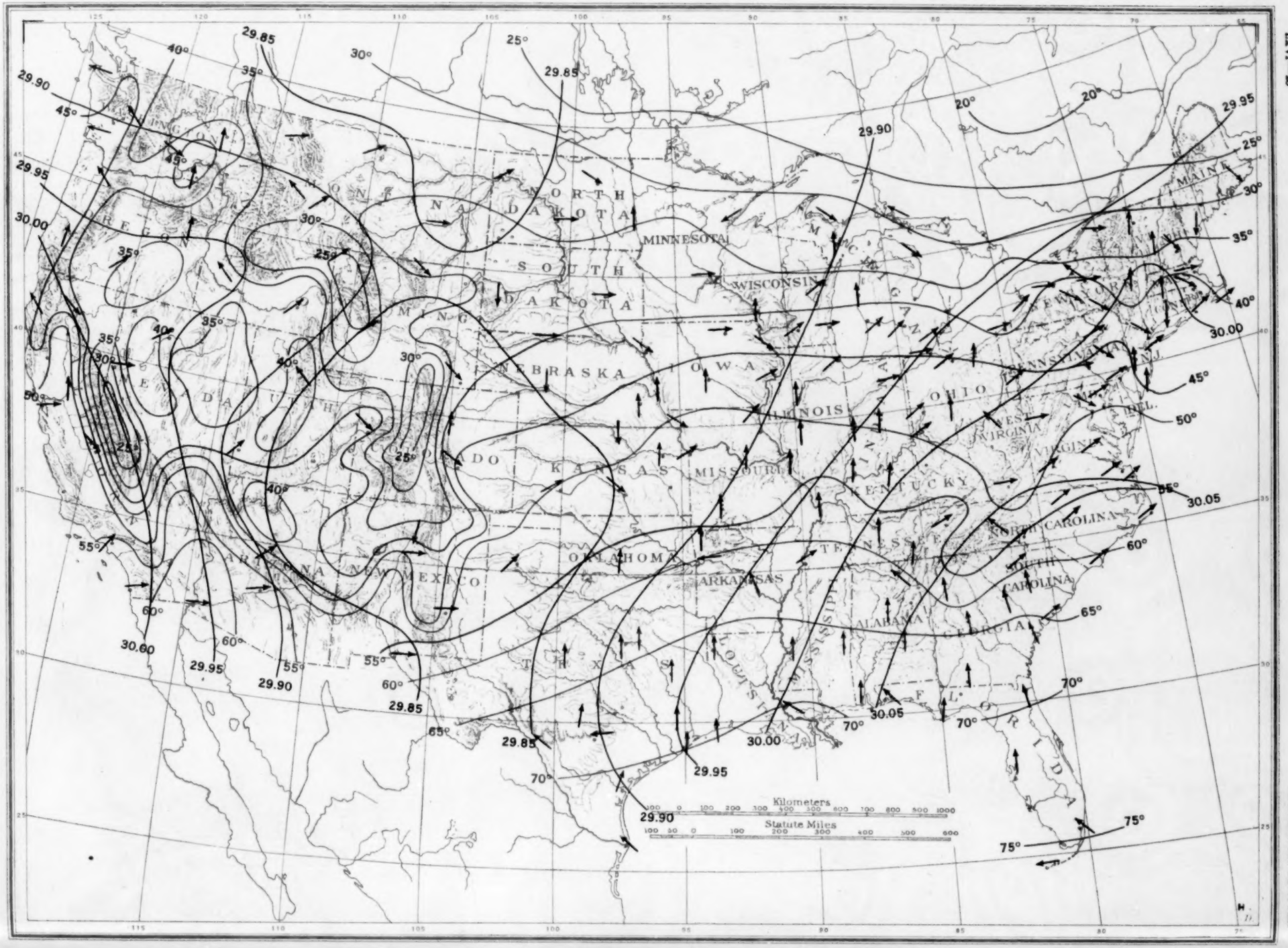

Chart VII. Wind Roses for Selected Stations, March 1938

(Plotted by W. W. Reed)

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Chart VIII. Total Snowfall, Inches, March 1938

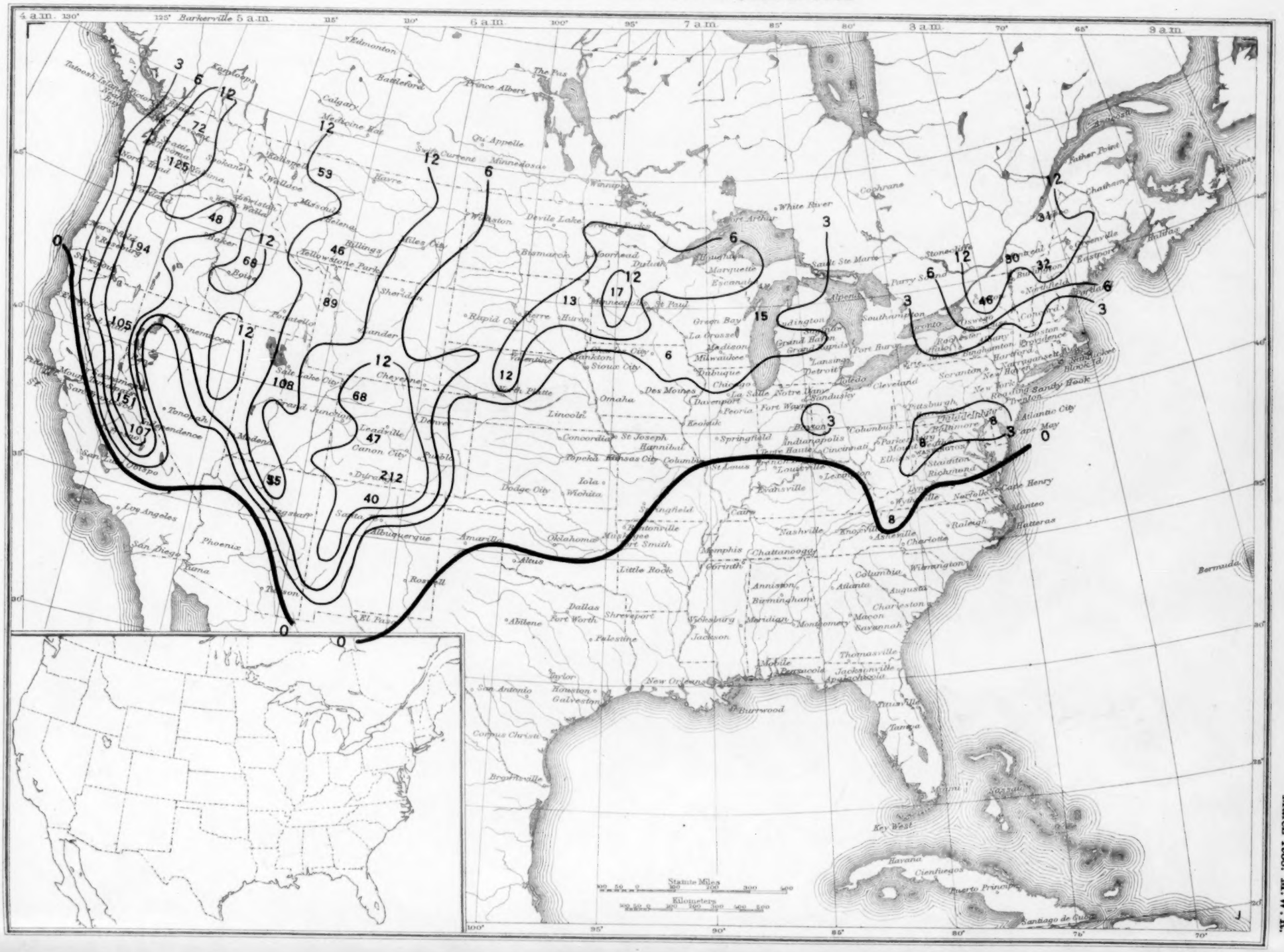

Chart IX. Weather Map of North Atlantic Ocean, March 12, 1938

(Plotted from the Weather Bureau Northern Hemisphere Chart)

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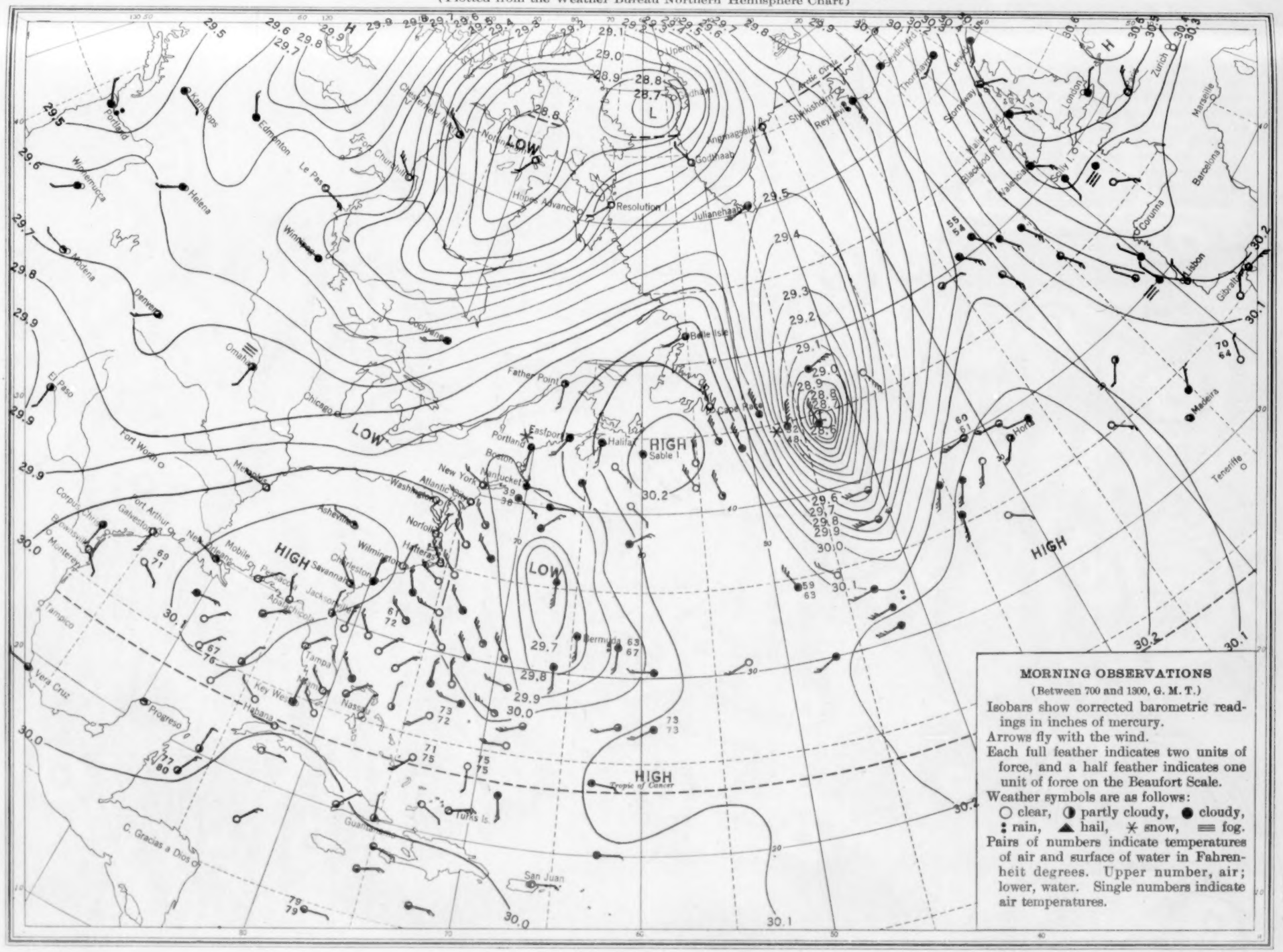


MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Each full feather indicates two units of force, and a half feather indicates one unit of force on the Beaufort Scale.

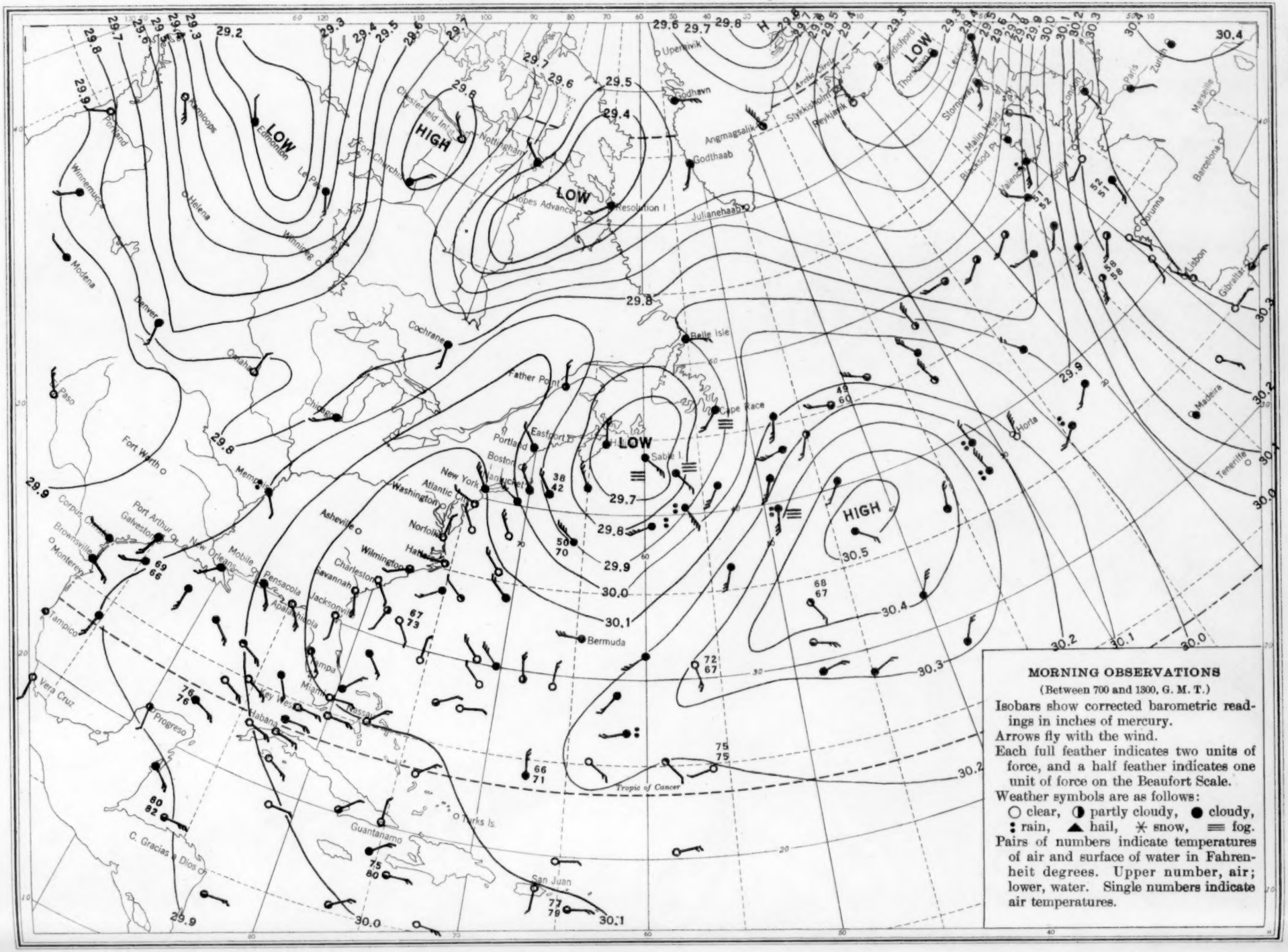
Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, : rain, ▲ hail, ✳ snow, ≡ fog.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart X. Weather Map of North Atlantic Ocean, March 19, 1938

(Plotted from the Weather Bureau Northern Hemisphere Chart)



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